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BULLETIN

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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

FOR THE

NEW YORK MEETING

FEBRUARY 23–25, 1939

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

at

COLUMBIA UNIVERSITY

and the

INTER-SOCIETY COLOR COUNCIL

at

480 LEXINGTON AVENUE

For Program of sessions of the Physical Society see Pages 5 to 20.
For Program of sessions of the Optical Society see Pages 21 to 24.
For Program of sessions of the Inter-Society Color Council see Pages 25 to 31.

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The American Physical Society

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BULLETIN

of the

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FEBRUARY 8, 1939 Vol. 14, No. 1, Part 1

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

NEW YORK MEETING, FEBRUARY 23–25, 1939

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

AND THE

INTER-SOCIETY COLOR COUNCIL

THE 226th regular meeting of the American Physical Society will be held in New York City on Thursday, Friday and Saturday, February 23, 24 and 25, 1939 as a joint meeting with the Optical Society of America and the Inter-Society Color Council. All regular sessions for the reading of contributed papers for both the Physical Society and the Optical Society will be held at Columbia University in the Pupin Physics Laboratories on 120th Street east of Broadway (entrance at 119th Street and Broadway). Sessions of the Inter-Society Color Council will be held on Thursday at 480 Lexington Avenue.

Joint Session. On Saturday morning at 10:00 o'clock there will be a joint session of the three societies in Studio 3A of the National Broadcasting Company, RCA Building, 30 Rockefeller Plaza. This session will be a symposium on *Television*. Cards of admission (no charge) will be available at the registration desk in Pupin Physics Laboratories on Friday.

Dinner. On Friday evening at 6:00 o'clock there will be a joint dinner for the members of the societies and their friends at the Columbia University Men's Faculty Club (corner of 117th Street and Morningside Drive). The President of the Physical Society, Dean John T. Tate of the University of Minnesota, will preside. The price of the dinner will be $1.25 per plate. Tickets will be on sale at the Pupin Physics Laboratories, Columbia University. Reservations should be made as early as possible and not later than Friday at 3 P.M.

Luncheon. On Friday and Saturday luncheon may be had at the Columbia University Men's Faculty Club. Further announcement will be made at the Friday and Saturday sessions.

GENERAL RULES RELATING TO PAPERS

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

> No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions

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to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

227. April 27–29, 1939. Washington, D. C.
228. June, 1939. Stanford University, Calif. Date to be decided.
229. June, 1939. Time and place to be decided.

W. L. SEVERINGHAUS, *Secretary*
Columbia University, New York, N. Y.

February 8, 1939.

CALENDAR

Thursday morning, February 23

9:30 o'clock: 480 Lexington Avenue: Business Session of the Inter-Society Color Council.

Thursday afternoon, February 23

2:00 o'clock: 480 Lexington Avenue: Technical Session on Color Tolerances: Jointly sponsored by the Inter-Society Color Council and the American Psychological Association. See pages 25–30.

Thursday evening, February 23

8:00 o'clock: 480 Lexington Avenue: Popular Session on *Parade of Color:* Inter-Society Color Council. See pages 30–31.

Friday morning, February 24

10:00 o'clock: Pupin Physics Laboratories: Room 818: Meeting of the Council of the Physical Society.

10:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society papers 1–10. See pages 5–7.

10:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society papers 11–18. See pages 7–8.

9:30 o'clock: Pupin Physics Laboratories: Room 428: Optical Society papers 1–4. See pages 21–22.

Friday afternoon, February 24

2:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society papers 19–27. See pages 8–10.

2:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society papers 28–36. See pages 10–12.

2:00 o'clock: Pupin Physics Laboratories: Room 428: Optical Society papers 5–9. See pages 22–24.

Friday evening, February 24

6:00 o'clock: Columbia University Men's Faculty Club: Joint dinner of the societies.

Saturday morning, February 25

10:00 o'clock: RCA Building, 30 Rockefeller Plaza, Studio 3A, National Broadcasting Company: Joint session of the societies: *Symposium on Television.* See page 13.

Saturday afternoon, February 25

2:00 o'clock: Pupin Physics Laboratories: Room 401: Physical Society papers 37–46. See pages 13–15.

2:00 o'clock: Pupin Physics Laboratories: Room 428: Physical Society papers 47–55. See pages 15–17.

2:00 o'clock: Pupin Physics Laboratories: Room 329: Physical Society papers 56–64. See pages 17–19.

The American Physical Society

PROGRAM

FRIDAY MORNING AT 10:00 O'CLOCK

Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 21–22)

1. Some Physical Properties of Liquid and Solid HD. F. G. BRICKWEDDE AND R. B. SCOTT, *National Bureau of Standards.*—About six liters of pure gaseous HD were separated from a mixture of H_2, HD and D_2 in a still having a refluxing column and operated in liquid hydrogen. Several properties of this sample of HD were measured with the following results: *Triple Point:* 16.60$_4$°K and 92.8$_8$ mm Hg. *Volume of Liquid* between triple point and 20.4°K: $V(\text{cm}^3\ \text{mol}^{-1}) = 24.886 - 0.30911T + 0.01717T^2$. *Relation between Freezing Temperature and Pressure* to $P = 80$ kg cm^{-2}: $\log_{10}(328.4+P) = 1.85904\ \log\ T + 0.24731$. *Latent Heat of Fusion* at triple point: 38.1 cal. mol^{-1}. *Latent Heat of Vaporization of Liquid* at 22.54°K: 257 cal. mol^{-1}. *Heat Capacity of the Solid:* varied regularly from 0.69 cal. mol^{-1} °K^{-1} at 12°K to 2.46 at the triple point. *Heat Capacity of the Liquid:* varied linearly from 4.48 cal. mol^{-1} °K^{-1} at the triple point to 6.29 at 22°K. The difference between the volumes of the liquid and solid phases at the triple point, calculated from the above data by means of the Clapeyron equation, is 2.66 cm^3 mol^{-1}. The following equations were found to represent the vapor pressure of HD[1] as a function of the temperature expressed on the scale[2] recently established at the National Bureau of Standards. *Solid* from 10.4°K to triple point, $\log_{10}P(\text{mm Hg}) = 4.70260 - (56.7154/T) + 0.04101T$. *Liquid* from triple point to 20.4°K, $\log_{10}P(\text{mm Hg}) = 5.04964 - (55.2495/T) + 0.01479T$. These properties of HD are compared with those of H_2 and D_2.

[1] R. B. Scott and F. G. Brickwedde, Phys. Rev. **48**, 483 (1935).
[2] H. J. Hoge and F. G. Brickwedde, Nat. Bur. Stand. J. Research **22**, March (1939).

2. Field Currents at High and Low Pressures. B. E. K. ALTER AND R. T. K. MURRAY, *Polytechnic Institute of Brooklyn.*—The fact that field currents can be obtained from metals immersed in gases at high pressure has been employed to study the field emission at high pressure and in a vacuum from the same cathode. The electrodes were steel spheres whose separation could be varied with a micrometer screw driven by an electric motor through reduction gears, the whole assembly being enclosed in a cylindrical steel container which could be evacuated or operated at pressures up to 130 atmospheres. Linear log current against reciprocal potential curves for constant distance, linear log current against distance curves for constant potential, and linear potential against distance curves for constant current were obtained. The measured fluctuations in the emission obtained in a vacuum were greater than those obtained at high pressure. Since under high pressure positive ion bombardment of the cathode is prevented, the observed fluctuations cannot be due to positive ion impact. This supports the theory that the emitting points are changed by local heating produced by the high current densities at the points. The increased fluctuations of the currents in a vacuum can be accounted for by positive ion impact on the cathode.

3. Field Measurements and Possible Correction of Aberrations for Magnetic Electron Lenses. L. MARTON, *389 Park Ave., Collingswood, New Jersey.*—Experiments with two magnetic coils indicate that an improvement in the image quality can be obtained by opposing the currents in the coils and placing the object between the two field maxima. The position of the object with respect to the latter may be determined by measuring the field distribution ballistically with a field coil. Applying the same method for studying the fields in an actual electron microscope, the latter are found to have maximum values of the order of 7000 gauss. Some general relationships between lens design and image quality are discussed.

4. Optical and Magneto-optical Activity of Nickel Sulfate, α-Hexahydrate, in the Short Infra-Red Spectrum. L. R. INGERSOLL, *University of Wisconsin;* PHILIP RUDNICK AND F. G. SLACK, *Vanderbilt University.*—Previous measurements[1] of the optical activity of crystalline nickel sulfate, α-hexahydrate, in the visible and near ultraviolet regions have indicated active absorption bands in the infra-red region. Measurements of the natural rotatory power, the Verdet Constant, and of the transmission for this crystal have now been made through the spectral range from 0.60 mu to 2.0 mu. The method used in measuring the rotations is a modification of that previously described by Ingersoll.[2] The results show distinct anomalies in both the optical rotation and the magneto-optical rotation at approximately 0.69 mu and 1.16 mu, with corresponding absorption in these regions. Curves will be presented. The anomaly occurring at 1.16 mu in the optical rotatory curve is an exceptionally good example of anomalous rotatory dispersion and indicates a relatively very strong term of the Drude type in the rotatory dispersion equation. Preliminary calculations indicate that the single electron model of Condon, Altar and Eyring[3] will not account for this activity but that it may be accounted for on the basis of a pair of coupled linear oscillators on a model proposed by Kuhn.[4] Work on the analysis of the experimental results is being continued.

[1] F. G. Slack and Philip Rudnick, Phil. Mag., in press.
[2] L. R. Ingersoll, Phys. Rev. **9**, 257 (1917).
[3] E. U. Condon, William Altar and Henry Eyring, J. Chem. Phys. **5**, 753 (1937).
[4] E. U. Condon, Rev. Mod. Phys. **9**, 446 (1937).

5. Magnetic Susceptibilities in Weak Fields. L. G. HECTOR AND MAHLON F. PECK, *The University of Buffalo.*—The Hughes induction balance method for measuring magnetic susceptibilities in weak fields first reported by Hector and Eckstein[1] has been improved in sensitivity to a point where diamagnetic liquids and some gases can be measured. The fields used vary from 5 to 35 oersteds. Carbon tetrachloride, benzene and toluene appear to have the same values of susceptibilities at these field strengths as are found when they are measured by classical methods in intense fields. On the other hand, present measurements indicate that water is approximately six percent more diamagnetic and oxygen approximately seven percent more paramagnetic in these weak fields than in the intense static fields ordinarily employed.

[1] L. G. Hector and G. R. Eckstein, Phys. Rev. **49**, 643 (1936).

6. Preparation of Single Crystals of Iron, Cobalt, Nickel and Their Alloys. P. P. CIOFFI AND O. L. BOOTHBY, *Bell Telephone Laboratories, Inc.*—The raw materials used were carbonyl iron, Katanga electrolytic cobalt and specially purified nickel. For all of the crystals except iron, the materials were further purified by heat treatment in pure moist hydrogen just below the melting point in a pure alumina crucible. The temperature was then raised until they melted together; subsequently, the temperature was lowered, in some cases automatically at the rate of 2°C/hour until solidification was complete. The alloys were homogenized by holding just below the melting point for 24 hours. Sometimes the resulting ingot was a single crystal weighing about 400 grams, more often it consisted of two or more crystals. A single crystal of cobalt weighing 300 grams was formed by this method in spite of the fact that it undergoes a phase transformation at 400°C. Smaller crystals (about five grams) of iron were made without melting by holding for a long time at 1480°C, then at 880°C in pure dry hydrogen. In the direction of the cubic axis the iron crystal was found to have a maximum permeability of 1,450,000 at $B=17{,}500$. The hysteresis loss and coercive force are considerably larger than have been expected for a crystal of this purity. The magnetic properties of the iron-nickel and nickel-copper crystals have been determined by Williams and Bozorth (see succeeding abstract).

7. The Magnetic Anisotropy of Iron-Nickel and Copper-Nickel Alloys. H. J. WILLIAMS AND R. M. BOZORTH, *Bell Telephone Laboratories, Inc.*—The magnetic anisotropy constant K_1 has been determined for nickel and a number of alloys of the Fe-Ni and Cu-Ni series. Specimens were cut from the large single crystals prepared by Cioffi and Boothby (see preceding abstract). The constants were determined either from torque measurements on single crystal disks in a magnetic field of high strength, or from the area between the magnetization curves for the [100] and [110] directions. For the latter method the specimens were cut in the form of hollow rectangles with each side parallel to a direction of the form <100> or <110>, as previously described.[1] For most of the crystals constants were determined at −196°C, 22°C and 200°C. For the two copper-nickel alloys (13 and 24 percent copper), K_1 was determined at a series of temperatures between −196 and 20°C and was found to obey the law: $K_1=K_{10}e^{-\alpha T^2}$, found to hold for nickel.[2] This relation permits extrapolation to 0°K. The constant so obtained (K_{10}) falls off rapidly with increasing copper content. In the iron-nickel series the composition for zero anisotropy is found to be near 70 percent nickel. Comparison is made with the data of others.[3]

[1] H. J. Williams, Phys. Rev. **52**, 747–51 (1937).
[2] N. L. Brukhatov and L. V. Kirensky, Physik. Zeits. Sowjetunion **12**, 602–9 (1937).
[3] J. D. Kleis, Phys. Rev. **50**, 1178–81 (1936).

8. Theoretical Constitution of Metallic Beryllium. CONYERS HERRING* AND A. G. HILL, *Massachusetts Institute of Technology.*—Preliminary results have been obtained in a theoretical calculation of the binding energy of metallic beryllium by the method of Wigner and Seitz. Assuming that the Fermi energy of an electron with wave vector k is proportional to k^2, the calculated binding energy is about 65 kcal./g atom. This can be compared with the value of 75 kcal./g atom estimated by means of the Born cycle method.[1] The ratio of the Fermi energy in the metal to that for completely free electrons in this approximation is 0.62, calculated by the method of Bardeen.[2] Calculations of the energies of some of the electronic states near the top of the Fermi distribution show that the above assumption is not very good, and that the final computed value of the binding energy may be expected to be much larger than 65 kcal./g atom.

* National Research Fellow.
[1] Bichowsky and Rossini, *Thermochemistry of the Chemical Substances* (1936).
[2] J. Bardeen, J. Chem. Phys. **6**, 367 (1938).

9. On the Theory of Paramagnetic Relaxation. J. H. VAN VLECK, *Harvard University.*—The times of relaxation associated with the transfer of energy between spin and lattice are computed for a specific model, *viz.* a titanium or chromium ion surrounded by six water dipoles, which was previously used by the writer[1] in connection with static susceptibilities. An explanation is obtained of why titanium alum shows[2] no dispersion at radio frequencies at liquid-air temperatures. However, the calculated relaxation time for titanium at helium temperatures is considerably greater than the value computed by Kronig,[3] and far too large for agreement with experiment[4] unless the elevation of the lowest excited states is of the order 10^2 cm^{-1}, rather than 10^3 cm^{-1} as apparently indicated by magnetic theory.[1] The calculated relaxation times for chrome alum are also probably somewhat too high, but the discrepancy is not as great. The use of a definite model thus apparently does not alleviate all the difficulties encountered in previous rather schematic calculations.[3, 5]

[1] J. H. Van Vleck, J. Chem. Phys. **7**, 61, 72 (1939).
[2] Gorter, Teunissen and Dijkstra, Physica, in press.
[3] R. de L. Kronig, Physica, in press.
[4] W. J. de Haas and F. K. du Pre, Physica, Nov. 1938.
[5] I. Waller, Zeits. f. Physik **79**, 370 (1932); W. Heitler and E. Teller, Proc. Roy. Soc. **155**, 629 (1936).

10. A Theory of Ferromagnetism. P. R. WEISS AND J. H. VAN VLECK, *Harvard University.*—An approach to the problem of ferromagnetism different from the well-known

Heisenberg approximation can be obtained from Bethe's[1] method for calculating the critical constants of the ordering phenomena in alloys. The interaction between a central atom and its nearest neighbors is taken into account rigorously while the effect of the atoms outside this first shell, which is supposed to be exerted on the central atom only through the first shell, is approximated by a Weiss field which acts only on the first shell. The central atom is exposed only to the external applied field. The Weiss field is then determined as a function of the external field simply by equating the moments of the central atom and of an atom in the first shell calculated in their respective fields. The critical point is that temperature at which the ratio of the Weiss field to the external field becomes infinite. Several lattice types have been investigated and their results will be given. An expansion of the partition function in powers of J/KT (J=the exchange integral) makes possible a comparison of the method with the rigorous theory as developed by Opechowski.[2]

[1] H. A. Bethe, Proc. Roy. Soc. **A150**, 552 (1935).
[2] W. Opechowski, Physica **4**, 181 (1937).

FRIDAY MORNING AT 10:00 O'CLOCK

Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 21–22)

11. The Lack of "Sucking" Action by the Cathode Blast of Mercury Vapor in a Pool Rectifier. L. TONKS, *General Electric Company.*—Experiments of von Engel and Steenbeck[1] point to a "sucking" action by the blast of mercury vapor leaving the cathode pool of a rectifier which operates on the side arms to reduce the vapor in them to but a small fraction of its value in the condensing dome. This effect has been sought using ionization gauges on a side arm and at the top of the condensing dome and using thermocouples on the tube wall at the mercury condensation edge and at the top of the dome. The rectifier used had a dome capacity of 2.2 liters and a diameter of 7.7 cm at the side arms which were 5 cm in diameter. Both with free and anchored cathode spot *no trace of "sucking" action was found.* Theory gives a maximum decrease of pressure to $\frac{1}{2}$ the dome value, compared to the value $\frac{1}{16}$ found by von Engel and Steenbeck. The experiments showed that with the anchored spot the vapor pressures were only $\frac{1}{2}$ to $\frac{1}{3}$ what they were with the free spot but that the wall temperatures were higher. Both factors are explained by the evaporation of the spray thrown by the free spot onto the hot tube walls.

[1] M. Steenbeck, Wiss. Veröff. a. d. Siemens-Werken **15** (3), 42 (1936).

12. Ultracentrifuge for Liquids.* A. VICTOR MASKET, F. W. LINKE AND J. W. BEAMS, *University of Virginia.*—The air-driven vacuum type tubular centrifuge[1] has been adapted to the separation of mixtures and solutions. The chamber surrounding the tubular centrifuge was evacuated to less than a micron to avoid heating. Vacuum pump oil was circulated by a pump first through a thermostat and then the vacuum-tight oil glands, rapidly enough to maintain the hollow shafts at constant temperature. This temperature was the same as that of the spinning tube. Machines with the air turbines above as well as below the vacuum chamber were used. The liquid material to be centrifuged entered at one end of the spinning tube through a hollow shaft at a continuous rate and was separated when it reached the other end into a light fraction at the center and a heavy fraction at the periphery. These two fractions flowed out of the spinning tube through separate partitions in a hollow shaft and were separately collected. A solid rod mounted coaxially and inside the spinning tube increased the efficiency. Auxiliary Oilite or Bakelite bearings prevented the materials being centrifuged from coming in contact with oil leaking from the vacuum-tight oil glands. All surfaces with which the material being centrifuged came in contact were stainless steel or gold plated.

* Supported by a grant from the Research Corporation.
[1] J. W. Beams, Rev. Sci. Inst. **9**, 413 (1938).

13. Separation of Bromine Isotopes by Centrifugation. RICHARD F. HUMPHREYS, *Yale University.*—A Beams air-driven ultracentrifuge has been used to obtain a partial separation of the bromine isotopes. The technique employed was that of "evaporative centrifuging" first suggested by Mulliken.[1] A working interpretation for the separation factor has been developed, and the theory given by Mulliken for the molecular weight gradient produced has been altered to cover the case of nonequilibrium set up by removal of the vapor from the rotor. There results an expression for rate of removal in terms of coefficient of diffusion of the gas and the degree of nonequilibrium. Ethyl bromide was centrifuged in a field of 388,000 g and removed in fractions of one-tenth, all transport of the material both to and from the rotor being accomplished by vacuum distillation to reduce evaporation losses to a minimum. The enrichments obtained have been determined spectroscopically by means of relative intensity measurements of isotopic lines in the spectra of AgBr and $H\,Br^+$.

[1] R. Mulliken, J. Am. Chem. Soc. **44**, 1033 (1922).

14. Formation and Properties of Unsupported Flowing Liquid Films. BRIAN O'BRIEN, *University of Rochester.*—If a continuous film of liquid is projected from a long narrow slot, the film will, in general, collapse a short distance beyond the orifice due to surface tension. This can be prevented by a suitable component of velocity of the emerging liquid. Such films in the form of figures of revolution are useful as transparent gas tight enclosures about

high intensity light sources, the liquid serving as a light filter. A 10-kw carbon arc has been operated for many hours within a water film in the form of a cylinder 8 cm diameter and 25 cm high without break in the flowing film. If broken such a film immediately reforms. Cylindrical films up to 30 cm diameter and 60 cm length have been produced in thickness of approximately $\frac{1}{3}$ mm. Their properties have been studied in some detail.

15. The Striated Luminous Glow of the Piezoelectric Quartz Resonator at Flexural Vibration Frequencies. J. R. HARRISON AND I. P. HOOPER, *Tufts College.*—Previous work has shown that the luminous glow due to the electrical discharge of a piezoelectric quartz resonator when vibrating in vacuum is sometimes striated in an unexpected way. This has been observed with X cut quartz rods vibrating at flexural vibration frequencies in the XY plane of the crystal. Double exposure photographs of this phenomenon are now shown which indicate the form and position of the striations on the quartz rod. The pressure of the residual gas and the applied voltage both have a marked effect on the position and number of the striations as is shown.

16. Nuclear Isomers in Radioactive Strontium. DAVID W. STEWART, *University of Michigan.* (*Introduced by J. M. Cork.*)—A further investigation has been made of the isomeric forms of Sr^{89} obtained in the bombardment of strontium with deuterons or neutrons. In agreement with earlier results,[1] the two periods of 3.0 hours and 55 days assigned to this isotope have been found to decay with the emission of negative electrons, producing stable Y^{89}. Accompanying the three-hour beta-activity is gamma-radiation, which is particularly interesting because it is complex and therefore of importance in interpreting the nature of the isomerism. The energy of this radiation has now been determined by the measurement of recoil electrons ejected from a carbon radiator in a 12-inch cloud chamber. From a distribution of 475 tracks, at least two gamma-ray lines have been identified, with energies of 0.55 and 1.1 Mev, and relative intensities of at least 3 : 1. This intensity ratio may actually be much greater, and may approach 10 : 1. By combining these data with those on the upper limits of the two beta-spectra, a tentative energy-level diagram has been derived which indicates that the metastable state of Sr^{89} decays in the three-hour period with beta-particle emission followed by gamma-radiation. The ground state of Sr^{89} decays directly in the 55-day period.

[1] D. W. Stewart, J. M. Cork and J. L. Lawson, Phys. Rev. **52**, 901 (1937).

17. The Band Structure of Metallic Copper. MARVIN CHODOROW, *Massachusetts Institute of Technology.*—A general method of calculating wave functions and energies of electrons in crystals, due to Slater,[1] has been further developed and applied to Cu. In this method, the wave function inside the inscribed spheres of the atomic cells is expanded in a series of radial functions and spherical harmonics. Outside these spheres, where the potential is approximately constant, the wave function is expanded in a series of plane waves. The method is found to be feasible only for highly symmetrical points of the Brillouin zone, e.g., $k=2\pi/a(0,0,0)$, $2\pi/a(\frac{1}{2},\frac{1}{2},\frac{1}{2})$, $2\pi/a(0,0,1)$. For other values of k, the calculations become too cumbersome. In the application to Cu, the potential used was not a Hartree self-consistent field but a semi-empirical potential obtained from consideration of the solutions (for $l=2$) of the Fock equations for Cu^+. This potential partially takes into account the exchange interaction of a "d" electron with the other electrons of the atom. The width of the bands containing the "d" electrons is found to be appreciably narrower (about 1.7 ev) than those calculated by Krutter.[2] The conduction band is very similar to one containing free electrons, but is split into two sections by the perturbations of the other bands.

[1] J. C. Slater, Phys. Rev. **51**, 846 (1937).
[2] H. Krutter, Phys. Rev. **48**, 664 (1935).

18. Reducing the Reflection from Glass by Multilayer Films. C. HAWLEY CARTWRIGHT AND A. FRANCIS TURNER, *Massachusetts Institute of Technology.*—The reflecting power of a glass surface may be reduced to substantially zero by a film having an optical thickness of about 1250A and an index of refraction of 1.2 to 1.3. The Lorentz-Lorenz equation indicates that the index of refraction can be lowered by decreasing its density and indeed the index of any evaporated material can be decreased to the desired value by controlling the evaporating conditions. However, a decrease in density below normal is accompanied by a decrease in mechanical strength, seriously limiting the number of the materials suitable for rugged single films. Zero reflection by the use of a single film occurs when the two reflection vectors add to zero. This result can also be attained by the use of multilayer films so applied that the three or more reflection vectors add to zero. An abnormally low index of refraction is no longer required and a greater choice both of film materials and methods of application is possible. A rather rugged transparent film which practically eliminated reflection of visible light was made by evaporating sapphire and then quartz.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Room 401

(For simultaneous session of the Optical Society, Room 428, see pages 22–24)

19. The Rossi Transition Curve for Small Angle Showers. W. M. NIELSEN, *Duke University.*—A study has been made of shower production in layers of iron over a range of thicknesses up to 320 g/cm². Simultaneous measurements of 7° showers and 28° showers were made with a counter arrangement similar to that recently employed.[1] With this arrangement a minimum of two particles from the producing material is necessary to discharge the four counters.

The results differ somewhat from those of Schmeiser and Bothe[2] in showing no significant increase in the prominence of a second maximum at about 220 g/cm² on the 7° curve compared with the larger angle shower curves. We conclude that the processes which contribute to the showers which are observed at the possible second maximum are not necessarily restricted to small angles.

[1] Karl Z. Morgan and W. M. Nielsen, Phys. Rev. **52**, 564 (1937).
[2] Schmeiser and W. Bothe, Ann. d. Physik **32**, 161 (1938).

20. The Design and Construction of Reliable Geiger-Müller Counters. GORDON L. LOCHER, *Bartol Research Foundation of the Franklin Institute.*—Some general features of design and construction of Geiger-Müller counters which are stable over long periods of use are reviewed, and some criteria for discrimination between acceptable and unacceptable practices are discussed on the basis of experience with the production of more than 1500 tubes. Desirable practices in the construction of ordinary γ- and β-ray tubes include: (1) the exclusive use of clean (heated) bare tungsten wires, (2) shielding of welds to prevent breakdown at sharp points, (3) removal of moisture and grease from all internal surfaces, (4) removal of any material from the cylinder which may become transferred to the wire, in use, (5) treatment of all internal surfaces to eliminate free alkali metals, or materials that may generate them, in use, (6) elimination of photoelectric response of the cathode to any light that can penetrate the glass envelope, (7) establishment of very high surface resistance of all internal insulating surfaces, (8) use of a gas content whose pressure is not too low and whose constitution will not alter with use, (9) avoidance of dust inside the tubes, and (10) the treatment of the external surface of the glass envelope to make the surface resistance extremely high. The localized character of the discharge of a normal counter (especially the high current density at the wire) makes it imperative that excessive current shall not be allowed to pass through the tube, in operation. It is pointed out that the probability of production of a spurious discharge in a faulty counter is usually highest immediately after a previous discharge; hence such counters may seem to have "high sensitivity" to radiation, and a relatively low background rate, whereas they are unreliable, and worthless for measurements. Some experiments with gas mixtures are discussed.

21. Comparison of Counter and Electroscope Measurements in the Stratosphere. S. A. KORFF AND W. E. DANFORTH, *Bartol Research Foundation of the Franklin Institute.*—Comparison of the several methods of measuring cosmic-ray intensities in the stratosphere is presented. It is shown that the results obtained by Millikan[1] using an electroscope and those found by Korff and Johnson[2] at about the same geomagnetic latitude using single Geiger counters are in good agreement. A geometrical factor is computed in order to take account of the different distributions of sensitive volume in the two cases. This comparison indicates that the correction to the electroscope observations due to the passage of simultaneous shower particles (or of single rays of great ionization) through it is less than ten percent. The observations of Korff, Curtiss and Astin[3] using low pressure counters are also found to agree with those of Millikan. It can be shown that such low pressure counters measure a quantity statistically proportional to the intensity observed with electroscopes. In so doing they take account of the passage through the counter of simultaneous shower rays and of rays of high specific ionization, while high pressure counters measure the number of ionizing events independently of the size of the event. The counter measurements made by Swann, Locher and Danforth[4] are found to be consistent with the electroscope measurements made by Millikan on the Settle-Fordney flight, but both give higher intensities at great altitudes than is found in the counter and electroscope flights made with small balloons. Hypotheses to explain this difference are discussed.

[1] I. S. Bowen, R. A. Millikan and H. V. Neher, Phys. Rev. **53**, 855 (1938).
[2] S. A. Korff and T. H. Johnson, Abs. Phys. Soc., Dec. 1938.
[3] S. A. Korff, L. F. Curtiss and A. V. Astin, Phys. Rev. **53**, 14 (1938).
[4] W. F. G. Swann, G. L. Locher and W. E. Danforth, J. Frank. Inst. **222**, 673 (1936).

22. The Origin of the Rays Which Produce the Bursts of Cosmic-Ray Ionization. C. G. MONTGOMERY AND D. D. MONTGOMERY, *Bartol Research Foundation of the Franklin Institute.*—The transmission through the atmosphere of the electrons and photons necessary to produce the observed size-frequency distribution of large bursts of cosmic-ray ionization is investigated. From the observations that the size-frequency distribution of bursts is independent of elevation, while the variation with elevation of the total number of bursts is not exponential, we conclude that the burst producing electrons are *not* transmitted through the atmosphere by the mechanisms of the cascade theory, but that in the lower atmosphere there must be a considerable number of electrons of high energy which are secondary to a penetrating component of the cosmic radiation. This conclusion is strengthened by observations of large showers from the air. It seems likely that these showers are also of secondary origin, since the spreading that a primary cascade would experience in traversing the atmosphere makes it unlikely that the observed high density of rays would occur by this process.

23. Electrophoretic Demonstration of Patent Pores of Human Skin. HAROLD A. ABRAMSON, *The Biological Laboratory, Cold Spring Harbor, and Mt. Sinai Hospital, New York.*—To investigate the paths by which the electrophoretic introduction of drugs into the intact human skin occurs, dyes of different charge like methylene blue and sodium prontosil were employed. Following electrophoresis of ½ percent methylene blue, the skin appears grossly to be uniformly dyed. The pattern of the patent pores which take a major part in the electrical transport of substances into the skin may then be developed by rubbing and washing vigorously to remove the most superficial layers of the skin. The developed pattern consists of many small uniformly stained, blue spots from about 0.07 mm to 0.5 mm in diameter. Practically all of the spots are at the site of the orifices of sweat glands (pores). Similar patterns are therefore obtainable in the palm of the hand. The patterns

persist for several weeks. During this time, the uniformly dyed pores decolorize in the center with the formation of circular or elliptical blue rings, doughnut forms, which surround the pore orifices. The pore pattern with negatively charged prontosil corresponds to the methylene blue pattern but persists only a few days. These results confirm the liquid bridge theory of skin permeability of Abramson and Gorin for the electrical transport of ragweed protein into the skin.

24. Compact Pressure-Insulated Electrostatic X-Ray Generator for Cancer Therapy. J. G. TRUMP AND R. J. VAN DE GRAAFF, *Massachusetts Institute of Technology.*—A compact, pressure-insulated, electrostatic x-ray generator has been developed for use in cancer treatment and research. A further object of the work was the investigation, using a small and thus flexible machine, of the design factors involved in pressure-insulated electrostatic generators with a view to the subsequent development of higher voltages in compact apparatus. The generator is housed in a steel tank 34 in. in diameter and 100 in. high. At air pressures of 10 atmospheres gauge, 1250-kv x-rays are obtained with currents of one milliampere on the single 14-in. belt. A substantial increase in voltage can be obtained by the use of Freon gas. The dependence of voltage and current on pressure and on gas is discussed. The problem of belt charge is analyzed and a method is described for controlling the electrostatic fields within the column in order to realize the high charge densities possible at high pressure. The construction of a supporting column of high breakdown strength, of the x-ray tube, and other features of the design are described. At 1250 kv the x-ray intensity per milliampere of target current is 250 roentgens per minute at 50 cm from the target in the direction of the electron beam with two-mm lead and five-mm copper filtration. The present work follows the development of a 1000-kv, air-insulated, x-ray source* which has been in use for almost two years at the Huntington Memorial Hospital.

* J. G. Trump and R. J. Van de Graaff, J. App. Phys. **8**, 602 (1937).

25. A Measurement of Gamma-Radiation in Roentgens. T. N. WHITE, *National Cancer Institute;* L. MARINELLI AND G. FAILLA, *Memorial Hospital, New York.*—For the measurement of gamma-rays in roentgens, certain requirements must be fulfilled. Heretofore most measurements of this type have been made by "thimble chambers" of small size placed at a distance from the source. The necessary conditions may be met also by a different geometrical arrangement of source and ionized volume, which offers certain advantages. With a small gamma-ray source at the center, measurements were made of the ionization in spherical air shells of thickness 0.04 to 3.5 cm and inner radii of 1 to 3.8 cm approximately. The air shells were defined by Lucite shells of suitable thickness. The gamma-ray output of radium in roentgens was obtained from these measurements by extrapolating to zero thickness of the air shell. By extending Lauritsen's analysis[1] of the influence of geometrical factors, a formula was derived which supplies a partial explanation of the variation of ionization in the air shells with respect to thickness.

[1] C. C. Lauritsen, Brit. J. Radiol. **11**, 471 (1938).

26. A Portable Gamma-Ray Detector. L. MARINELLI, *Memorial Hospital, New York.*—The use of a commercial grid glow tube (KU 618) as a point counter will be described. The circuit requires essentially a 0.01-mf condenser, a resistance of five megohms and a source of potential of about 200 volts. The instrument provides a rather inexpensive means for the detection of gamma-ray sources and stray radiation as well as for demonstrations in radioactivity. An a.c. operated instrument, provided with a counting circuit and weighing seven pounds, will be shown. In its present form the natural counting rate of the device increases tenfold when exposed to the gamma-radiation of five mg of radium at a distance of five meters.

27. Some New Features in the Million-Volt X-Ray Installation at the Memorial Hospital. G. FAILLA, *Memorial Hospital, New York.*—The General Electric Company announced recently the completion of a million-volt x-ray generator to be installed in the new Memorial Hospital. For the accurate treatment of patients it is very desirable that the beam of radiation be adjustable in direction through 90° in a vertical plane. Since the generator weighs about two tons it is simpler to move a "collimator" with respect to the tube target. If the collimator is made of overlapping five-inch thick lead plates the device becomes too cumbersome. To provide a beam of x-rays which is adjustable both as to direction and cross section, the target is surrounded by a mercury tank into which is inserted at the appropriate angle a hollow "cell" of the proper shape and size. It is important to keep the patient under observation during the treatment. To accomplish this a window is provided in the thick concrete wall at one corner of the treatment room. A glass cell which fits into this window is filled with a transparent salt solution of sufficient absorptive power to protect the observer from scattered x-rays.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Room 329

(For simultaneous session of the Optical Society, Room 428, see pages 22–24)

28. The Effect of Pressure on the Intensity of the Recombination Spectrum of Mercury. ROBERT C. GARTH, *Brooklyn College;* GEORGE E. MOORE, *Bell Telephone Laboratories;* AND HAROLD W. WEBB, *Columbia University.*—The effect of vapor pressure on the intensity of spectral lines in the recombination glow of mercury vapor

was investigated. The pressure was varied from 0.1 mm to 1.7 mm and the concentration of ions maintained at approximately 2.5×10^{11} per cc as measured by the Langmuir probe method. The combined intensity of 5461 and 5770–90 was measured with a photometer, and photographic methods were used for measuring other lines in the visible and ultraviolet. It was found that the intensities in general increased with pressure, although the exact behavior of a line depended on its position in the spectral series. This result indicates that the rate of recombination is a function of the concentration of the neutral atoms as well as of the recombining ions and electrons, or that the metastable and other excited atoms influence recombination. The band spectrum of mercury was observed at pressures above 1.0 mm.

29. The Spectral Distribution of Energy in the Recombination Spectrum of Mercury. GEORGE E. MOORE, *Bell Telephone Laboratories;* ROBERT C. GARTH, *Brooklyn College;* AND HAROLD W. WEBB, *Columbia University.*—The distribution of energy in the recombination (afterglow) spectrum of Hg was measured in the spectral range from 2200A to 20,000A. The relative intensity of the strongest lines was found to vary in much the same way as in the arc. The intensity of the higher lines was relatively much stronger than in the arc so that the computed population of some of the higher energy levels was greater than for the lower levels in the same series. By determining the quanta due to radiative transitions into and out of various spectral levels, it was shown that most of the recombination occurred directly into the levels about 1.5 to 2.5 volts below the ionization potential. Continua were observed beyond the limits of eight different series, all being much less intense than the strong lines of the series. The dependence on the concentration of ions was studied and it was found that the intensity of the higher lines increased more than that of the lower. Recombination coefficients were calculated from the absolute intensities.

30. Spectra of SnH and PbH at High Pressure. W. W. WATSON AND R. SIMON, *Yale University.*—Although no band spectra are produced by Sn or Pb arcs in hydrogen at low pressure, a number of SnH and PbH band systems appear in a d.c. arc in hydrogen at four to five atmospheres pressure. A (0,0) $^2\Delta\rightarrow{}^2\pi$ transition for SnH has first heads at 4054A and 4447A. The analysis gives $B=5.31$, $A=2182.7$ for $^2\pi$, $B=4.91$, $A=-1.75$ for $^2\Delta$ and shows a sharp cutoff at $K'=17$. The apparently analogous transition for PbH occurs in the near ultraviolet, one principal head lying at 3810A. In the red and infra-red regions both molecules have spectra with unique intensity anomalies, such as a variation in the relative intensities of band branches with v, probably attributable to a near approach to case c conditions. The PbH red spectrum already described[1] has been extended to 9100A, revealing an additional electronic transition. The operation of the high pressure arc and its usefulness in the investigation of molecular spectra are discussed.

[1] W. W. Watson, Phys. Rev. **54**, 1068 (1938).

31. Binding Energy of He^6 and Nuclear Forces. HENRY MARGENAU, *Yale University.*—The binding energy of He^6 is known from the experiments of Bjerge and Broström. In all probability, the ground state of this nucleus is a ^1S state, while the normal state of Li^6 is ^3S. The difference in the binding energies of these two nuclei which is due to the specific nuclear forces (after correction for the difference in the Coulomb energies) is known to be 3.7 ± 0.7 Mev. This value is nicely accounted for theoretically with the use of the customary nuclear parameters if the calculation is carried as far as the Feenberg-Wigner approximation.[1] The question arises as to the value of this difference when excited states are included in the perturbation calculation of the energies of the two nuclei. To answer it, a computation has been made for the ^1S state of the six-body problem similar to that for Li^6.[2] All doubly-excited states, but no others, were included. In zeroth order one obtains for the difference in the binding energies: $\Delta=2g(1-2u+5u^2)(\sigma u)^{3/2}(35.6)$ Mev, and this is equal to 3.7 Mev if the minimizing parameter σ has the same value as for Li^6 (1.4) and g, the ratio of Heisenberg to Majorana forces, is taken to be 0.23. However, with the inclusion of the doubly-excited states, the value of Δ drops to 1.26 Mev for $g=0.20$, to 1.53 Mev for $g=0.25$. Hence the agreement obtained in the Feenberg-Wigner approximation, which gives a very poor answer for the total binding energy of Li^6, is considerably disturbed when attention is given to excited states.

[1] E. Feenberg and E. Wigner, Phys. Rev. **51**, 95 (1937).
[2] H. Margenau and K. G. Carroll, Phys. Rev. **54**, 705 (1938).

32. The Theoretical Binding Energy of He^5. WARREN A. TYRRELL, JR., *Yale University.*—The binding energy of the unstable nucleus He^5 has been calculated both perturbationally and variationally. The functions employed are single particle Legendre functions. The zero-order approximation corresponds to an alpha-particle in the ground state and a p neutron. With values of the nuclear constants previously used,[1] H_{00} is -11.5 Mev. The second-order perturbation contributions of the doubly and quadruply excited functions lower this to -17.8 Mev. The convergence limit for functions of all degrees of excitation will be discussed. Variational calculations have been made with two variation parameters, one for four s particles forming an alpha-particle, and one for a p neutron. With the simplest symmetrized wave function, the plot of the energy E against the two variation parameters shows no minimum. For values of the alpha-particle parameter compatible with He^4 alone, the plot of E against the neutron parameter is almost horizontal for a certain range of the latter. This is in accord with expectation; moreover, the value of E in this region is in fair agreement with the experimentally determined instability.[2] A more refined variational calculation is in progress.

[1] H. Margenau and W. A. Tyrrell, Phys. Rev. **54**, 422 (1938).
[2] J. H. Williams, W. G. Shepherd and R. O. Haxby, Phys. Rev. **52**, 390 (1937).

33. Energy Levels of H^3, He^3 and He^5. KATHARINE WAY, *Bryn Mawr College.*—Wheeler's method of reso-

nating groups was applied to the three-body nuclear problem. Particles 1 and 2 are considered the like particles. The wave function Ψ is then written:

$$\Psi = S_1 F[(r_2+r_3)/2-r_1]\varphi(r_3-r_2) - S_2 F[(r_1+r_3)/2-r_2]\varphi(r_3-r_2)$$

where the S's are appropriate spin functions and the φ's are deuteron wave functions which were found by numerical integrations of the deuteron wave equation. F is determined by the requirement that $E=\int\psi^* H\psi d\tau / \int\psi^*\psi d\tau$ be a minimum. V_{ij} was written $V_{ij}=-Ae^{-ar_{ij}^2}[(1-g-g_1-g_2)P_{ij}^M+gP_{ij}^H+g_1]+g_2P_{ij}^B]$ with $A=72\ mc^2$ and $1/a^{\frac{1}{2}}=2.25\times10^{-13}$ cm, and $g+g_2=0.22$. In the He problem the Coulomb term was added to V_{12}. For the state $S=\frac{1}{2}$, $L=0$, $g+g_2$ is the only important combination. The calculated energies of this state are -6.1 mMU for He^3 and -6.7 mMU for H^3. Experimental binding energies are 8.1 and 8.9 mMU, respectively. For the state $S=3/2$, $L=0$, $1-3g_1-3g_2$ is the decisive factor. Values of this combination which lead to bound states will be discussed. In the five-body problem when an approximate wave function $Ze^{-\beta R^2}$ (P state) was used for $F[(r_1+r_2+r_3+r_4)/4-r_5]=F(R)$ no virtual level of He^5 was found for any reasonable value of $1+g-5g_1-3g_2$.

34. A Study of Radioactive Be^7. J. E. Hill and G. E. Valley, *University of Rochester.*—This isotope[1] (43 day) has been formed by bombardment of Lithium with protons of energies up to 6.5 Mev. The threshold for the reaction Li^7 (p, n) Be^7, determined by studying the 2.3-min. activity induced by the neutrons in silver plus paraffin, is 1.75 ± 0.05 Mev. This means that the mass of Be^7 exceeds that of Li^7 by 1.0 ± 0.05 Mev. The γ-ray spectrum of Be^7 is being closely examined both by cloud chamber and magnetic spectrograph to determine whether or not radiation other than the prominent 0.44 Mev line is present. In order that these results may not be inconclusive, the secondary electrons measured are recoils from aluminum 25 mg/cm² thick. If such radiation (e.g. annihilation) is present, its intensity is less than ten percent of the 0.44-Mev line. A Be^7 source less than one mg/cm² thick, and emitting about 10^4 quanta/sec., showed no definite evidence of positron emission, when examined in a cloud chamber filled with hydrogen at 110 cm Hg pressure. This is in agreement with previous results, and with the mass difference determined from the $p-n$ threshold.

[1] L. H. Rumbaugh, R. B. Roberts and L. R. Hafstad, Phys. Rev. **54**, 657 (1938).

35. On the Self-Energy of the Electron. Viktor Weisskopf, *The University of Rochester.*—The self-energy of the electron can be divided into two parts: the energy of the electrostatic field of the charge distribution and the energy of the interaction with the radiation field. It can be shown that in the quantum theory for a single electron the first part diverges linearly, as one expects for a charge with infinitely small radius. In the positron theory, however, this energy diverges logarithmically, which can be explained by the peculiar interaction between the electron and the vacuum. This effect is essentially connected with the exclusion principle. Any theory of particles with Bose statistics leads to a quadratically divergent electrostatic self-energy. The energy of interaction with the radiation field is mainly due to the oscillations of the electron under the influence of the field fluctuations of the empty space. This energy diverges quadratically. In the positron theory, however, this term is canceled by another energy term, due to the current fluctuations of the vacuum. Here again the exclusion principle is essential. In Bose statistics the corresponding term has opposite sign, so that the total electrodynamic self-energy also diverges quadratically. Thus the "critical length" in the positron theory is about $l\sim(h/mc)e^{137}$ whereas a theory with Bose statistics leads to $l\sim(h/mc)(137)^{-\frac{1}{2}}$.

36. Competition Between $p-n$ and $p-\gamma$ Reactions. Charles V. Strain, *The University of Rochester.*—When nickel is bombarded by high energy protons Cu^{61} (3.4 hr.), Cu^{62} (10.5 min.) and Cu^{64} (12.8 hr.) are formed. Each of the first two activities might be formed by either a $p-\gamma$ or a $p-n$ reaction; namely, (1) $Ni^{60}(p-\gamma)Cu^{61}$, (2) $Ni^{61}(p-n)Cu^{61}$ (threshold 2.9 Mev), (3) $Ni^{61}(p-\gamma)Cu^{62}$, (4) $Ni^{62}(p-n)Cu^{62}$ (threshold 4.6 Mev).

In a previous article[1] evidence was given that Cu^{62} was formed by (3) at proton energies below the threshold for reaction of (4). A cloud-chamber study of the positron spectra confirms this conclusion. With proton energies above the threshold of (2) (2.9 Mev) Ni^{61} can be transmuted by either a $p-\gamma$ or a $p-n$ reaction. From the excitation curves of the Cu^{61} and Cu^{62} activities the relative probabilities of the two reactions can be obtained in the energy range of 2.9 to 4.6 Mev. The ratio of the intensities of the $p-\gamma$ to the $p-n$ reaction of the nucleus Ni^{61} can be computed after correcting for the disturbing effect of the Ni^{60} $p-\gamma$ effect. This ratio falls sharply from a high value at three Mev to a value much smaller than $\frac{1}{3}$ at 4.5 Mev. This is a good illustration of the rapidly increasing probability of neutron emission with increasing velocity of the neutron.

[1] C. V. Strain, Phys. Rev. **54**, 1021 (1938).

SATURDAY MORNING AT 10:00 O'CLOCK

National Broadcasting Company

RCA Building, 30 Rockefeller Plaza

Studio 3A

Joint Session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council

SYMPOSIUM ON TELEVISION

Invited Papers

1. **Electron Optics as Applied in Television Systems.** V. K. ZWORYKIN, *RCA Manufacturing Company*
2. **Application of Electron Multipliers to Voltage Amplification.** P. T. FARNSWORTH, *Farnsworth Television, Incorporated*
3. **Demonstrations in Television.** A. F. VAN DYCK, *Radio Corporation of America*

Cards of admission will be required for this symposium and may be obtained by members of the societies without charge at the registration desk in Pupin Physics Laboratories on Friday.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 401

37. Resonance Scattering of Protons by Lithium. EDWARD CREUTZ, *University of Wisconsin. (Introduced by G. Breit.)*—The scattering of protons from a thick lithium target has been studied in the energy region 260–600 kev at a scattering angle of 156°, using a ball counter. The number of counts per microcoulomb at 458 kev is 2.1 times the value at 408 kev and at 486 kev it has dropped to 1.41 times the value at 408 kev. The observed resonance peak is distorted by absorption of protons scattered deep in the target, but this effect is least for the low energy side, where the curve shows a maximum slope at the same proton energy as the lithium gamma-ray resonance within ±5 kev. Since the effect of absorption tends to move the maximum slope to lower energy, the lower limit of the scattering resonance maximum at 156° is 435 kev, assuming 440 kev as the resonance maximum for the 17-Mev gamma-radiation. The scattering from a thick Be target was found to increase smoothly with energy showing that the resonance effect is not a peculiarity of the counter. This scattering anomaly has been suggested by Professor Breit to indicate that the gamma-radiation obtained when Li^7 is bombarded with 440-kev protons arises from a virtual level of Be^8, and not from an excited alpha-particle, a previously tenable alternative hypothesis.

38. The Scattering of Neutrons by Hydrogen and Deuterium Molecules. MORTON HAMERMESH, *New York University,* AND JULIAN SCHWINGER, *Columbia University.*—The general method of treating the scattering of neutrons by molecules, taking account of the spin dependence of nuclear forces and the symmetry properties of molecules containing several identical particles, has been given by Schwinger and Teller, and applied by them to H_2. We have extended their calculations to a wider range of neutron energies and to several other transitions, and applied them to an analysis of the experimental data of Dunning *et al.* We find that their data can be fitted with a neutron-proton scattering cross section of $(20\pm2)\cdot10^{-24}$ cm², verifying the result obtained by direct measurement; but simultaneous agreement for both *ortho* and *para* H_2 can be obtained only by assuming a departure from thermal equilibrium in the form of a decreased number of neutrons in the region below ~0.01 ev and a possible high energy "tail." The larger value of the neutron-proton cross section increases the elastic scattering of *para* H_2, and makes it more susceptible of measurement. It has already been emphasized that such experiments would enable a determination of the range of the neutron-proton interaction in the triplet state. Calculations have been made for the scattering by *ortho* and *para* D_2, assuming various values of the scattering amplitudes for the doublet and quartet states. From such measurements, the values of these amplitudes may be deduced, thus affording an important source of information concerning nuclear forces.

39. The Scattering of D−D Neutrons. S. SEELY, W. H. ZINN AND V. W. COHEN, *Columbia University.*—Measurements of the total scattering cross sections of various elements for the 2.8-Mev neutrons from the D−D reaction previously reported by us[1] have been extended to a

greater number of elements. The cross sections vary quite irregularly with atomic weight. Measurements of the cross sections of some elements for 2.4-Mev neutrons have also been made. Oxygen, in particular, showed a change in cross section with the change in energy of the incident neutrons. The neutron detection system consists of a small helium-filled ionization chamber two cm in diameter at a distance of 32 cm from the target. The ionization chamber is coupled to a linear amplifier, the associated scaling unit being so adjusted as to record only those pulses, as observed in an oscillograph, approximately twenty times the background.

[1] W. H. Zinn, S. Seely and V. W. Cohen, Phys. Rev. **53**, 921(A) (1938).

40. Elastic Scattering of Fast Neutrons. R. F. BACHER, *Cornell University.*—Experiments have been carried out to ascertain the albedo effect of fast neutron scattering by Pb. The source of neutrons was a Be target located in a brass tube outside the cyclotron chamber proper, and bombarded with 5 to 10 μa of 1.5-mv deuterons. Fast neutrons were detected by a Cd-shielded Al detector which gave the 10-minute period of Mg^{27}. The activity of the detector which was placed four cm from the source was taken with and without Pb surrounding detector and source. When Pb was placed between source and detector, activity was reduced to 65 percent. When both source and detector were surrounded with Pb there was a slight increase in activity. The slight increase observed may well be due to the difficulty of repeating the irradiation. This result indicates that at least the greater part of the scattering is inelastic, with loss of energy by the neutrons sufficiently large so that they no longer activate the Al. This result is in agreement with the large energy losses observed for neutrons which have passed through Pb, but is in disagreement with various determinations* of the amount of elastic scattering which indicate from 60 to 90 percent.

* D. C. Grahame and G. T. Seaborg, Phys. Rev. **53**, 795 (1938); E. Hudspeth and T. W. Bonner, Phys. Rev. **53**, 928(A) (1938).

41. The Ionization Produced in Gases by Fast Neutron Irradiation. PAUL C. AEBERSOLD* AND GLADYS A. ANSLOW,** *University of California.*—A collimated beam of fast neutrons was directed along the axis of a cylindrical, brass ionization chamber of 100 cc volume and the ionization produced in fourteen gases at pressures from three mm of Hg to three atmospheres was investigated using an electrometer tube measuring device. The source was beryllium bombarded by deuterons accelerated to eight Mev in a cyclotron. The collimation was achieved by a channel through a water tank, the channel and the outside of the tank having thick walls of Pb to absorb gamma-rays produced in or scattered from the tank. To suppress gamma-rays from the source the beam was filtered through three cm of Pb. That the main ionization with such an arrangement is due to neutrons can be seen from the very different relative ionization in the various gases compared to that for gamma-rays alone. Moreover, calculations by two methods give small values for the percentage contribution by gamma-rays to the measured ionization. Subtracting this small contribution, the ionization due to neutrons alone is deduced and related to the values to be expected from the production of recoil nuclei in the gas by elastic scattering. The agreement with expectation using Dunning's cross sections is excellent except for N_2 and A for which disintegrations by neutron absorption are appreciable. The results show particularly that the relative ionization in various hydrogenous materials by fast neutrons can be closely approximated on the basis of elastic scattering of the neutrons.

* Fellow of the Finney-Howell Foundation.
** On sabbatical leave from Smith College.

42. On the Nuclear Moments of the Rubidium and Chlorine Isotopes. P. KUSCH AND S. MILLMAN, *Columbia University.*—A comparison of the ratios of the nuclear magnetic moments of two isotopes of the same element as obtained from an observation of hyperfine structure and as found by direct observation tests the validity of the assumption that magnetic interaction between the nuclear moment and the electronic structure is sufficient to explain observed h.f.s. splittings in atomic energy levels. We have applied the molecular beam resonance method to a measurement of the nuclear moments of Rb^{87} and Rb^{85}. Using Rb_2 molecules, the observed resonance minima and the known values of nuclear spins yield 2.730 and 1.340 as the moments of Rb^{87} and Rb^{85}, respectively, referred to the moment of Li^7, 3.250 nuclear magnetons. The observed ratio, $\mu_{Rb^{87}}/\mu_{Rb^{85}}=2.037\pm0.5$ percent, is to be compared with the ratio 2.026 ± 0.2 percent found by Millman and Fox,[1] who measured the h.f.s. of the ground states of the rubidium isotopes by the atomic beam zero moment method. In view of the precision of the present result it is not certain that this difference represents a real physical effect. The nuclear g's of Cl^{35} and Cl^{37} have also been measured. The g values of these two nuclei are 0.546 ± 0.5 percent and 0.454 ± 0.5 percent, respectively. The spin of Cl^{35} is probably 5/2 from the measurements of Elliott[2] on the alternating intensities in band spectra. The moment of Cl^{35} is then 1.365 nuclear magnetons. No information on the spin of Cl^{37} is available.

[1] S. Millman and M. Fox, Phys. Rev. **50**, 220 (1936).
[2] A. Elliott, Proc. Roy. Soc. **127A**, 638 (1930).

43. The Electric Quadrupole Moment of In^{115}. DONALD R. HAMILTON AND NICHOLAS A. RENZETTI, *Columbia University.*—The h.f.s. $\cos^2$ interaction ascribed to a nuclear electric quadrupole moment, Q, has been investigated in the $^2P_{3/2}$ metastable state of In^{115} using the zero moment method of atomic beams.[1] Schüler's and Schmidt's spectroscopic determination of Q, using this state,[2] utilizes three h.f.s. separations; the present method takes advantage of 13 observables, i.e., the fields for zero moment peaks arising from certain of the 40 magnetic levels. These peaks are sensitive to Q; order is reversed and peak ratios, often measurable to $\frac{1}{4}$ percent, are sometimes changed by 30 percent. Their behavior is completely described in terms of the nuclear g factor,[3] the electronic g factor, and constants of the equation $\Delta\nu_F=(aC/2)+bC(C+1)$ giving the position of the levels in zero field. $(C=F(F+1)-I(I+1)$

$-J(J+1)$.) The first term is the usual interaction. The second arises from Q; the constant b, involving atomic wave functions, is directly proportional to Q. Observed peak ratios determine b/a to one percent; a is obtained by field calibration in terms of the first peak of the *Cs* ground state and the $\Delta\nu$ of this state, 0.3067 ± 0.0004 cm^{-1}.[4,5] We find $a=(8.11\pm0.04)\times10^{-3}$ cm^{-1} and $b=(0.0521\pm0.0007)\times10^{-3}$ cm^{-1}. This gives an actual h.f.s. separation 0.1186 ± 0.0007 cm^{-1}, or 0.1217 ± 0.0006 cm^{-1} for $Q=0$. Schüler and Schmidt give $a=7.97$, $b=0.048$, and total separation 0.120 cm^{-1}. Our b is eight percent higher than their 0.048, from which they deduce $Q=0.8\pm0.2$.

[1] V. W. Cohen, Phys. Rev. **46**, 713 (1934).
[2] H. Schüler and T. Schmidt, Zeits. f. Physik **104**, 468 (1937).
[3] I. I. Rabi, S. Millman and J. R. Zacharias, Phys. Rev. **53**, 384 (1938).
[4] L. P. Granath and R. K. Stranathan, Phys. Rev. **48**, 725 (1935).
[5] S. Millman and M. Fox, Phys. Rev. **50**, 220 (1936).

44. The Temperature in White Dwarf Stars. R. E. MARSHAK AND H. A. BETHE, *Cornell University.*—It is usually assumed that the temperature in a white dwarf is almost constant over the degenerate interior and changes appreciably only in the nondegenerate surface layer. For the temperature at the boundary of the two regions in Sirius B, values between $2\cdot10^7$ (Stromgren) and $6\cdot10^7$ degrees have been given. These values seem to be too high, due to the use of incorrect opacity laws. The actual opacity is 5 to 100 times less than the Kramers value, resulting in a boundary temperature of 0.8 to $1.0\cdot10^7$ degrees. In the interior the energy transport is mostly by conduction, conduction and radiation being about equally important at the boundary. There is an appreciable increase of temperature from the boundary to the center where $T\approx2.5\cdot10^7$ degrees. These high temperatures are only reconcilable with the observed small luminosity if the hydrogen content is very low. The transition region from nondegenerate to degenerate gas cannot be treated by the methods previously used in astrophysics which give much too low values for the density of free electrons. Instead, we propose to use the Thomas-Fermi equation with finite boundary conditions as for metals. This equation has been generalized to include the effect of finite temperature and a mixture of elements.

45. The Self-Energy of the Electron. H. A. BETHE, *Cornell University.*—It has never been decided whether the divergence of the self-energy of the electron is inherent in the fundamental equations of quantum electrodynamics or is due to the use of perturbation methods in their integration. We have found an almost exact method of integration for the particular case of the nonrelativistic Schrödinger theory. In this theory, only the A^2 term in the interaction between electron and (transverse) electromagnetic field need be considered but not the $A\cdot p$ term. In first approximation, the well-known result for the self-energy is obtained, *viz.*

$$W_1\approx\frac{hc}{r_0}\frac{e^2}{mc^2r_0}$$

where r_0 is the "cutting-off" radius. Successive approximations differ by a factor $\gamma=e^2/(mc^2r_0)$ and have alternating sign. For very large γ, perturbation theory is no longer valid; the radiation field will then in general contain many quanta. But just this fact can be used for the integration because the total energy of n quanta ($n\gg1$) will differ only slightly from its mean value of $2nhc/r_0$. Using this mean value instead of the actual energy, the rest of the integration can be carried out exactly and gives for the self-energy the value, $W\sim(hc/r_0)\gamma^{\frac{1}{2}}\sim r_0^{-\frac{1}{2}}$. This shows that the divergence is inherent in the fundamental equations and cannot be removed by improved methods of integration.

46. General Relativity Theory and Flat Space. N. ROSEN, *Massachusetts Institute of Technology.* (*Introduced by M. S. Vallarta.*)—At present it appears that gravitation is unimportant in the problem of the nucleus. It may be that it is actually of fundamental significance in determining nuclear forces but that existing theories have to be modified in order to show it. As a first step in the search for a suitable modification, the problem is considered of treating the general theory of relativity from the standpoint of an underlying flat space. In this way some properties of gravitational forces are obtained.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 428

47. On Thermal and Stress Dependence of Elasticity in Solids. H. LUDLOFF, now at *Cornell University.* (*Introduced by H. A. Bethe.*)—Previously a method was devised by which the elastic constants are determined from the interference figures occurring in diffracting light from ultrasonics in solids. From the interference figures the directional dependence of thermal waves in an atomic lattice can also be directly obtained, so that in related thermodynamical investigations tedious calculations can be avoided. The original theoretical basis of the method can now be further generalized at two points: (1) The change in the interference figures, when the solid is transformed from the elastic to the plastic state, can now be quantitatively determined; and conversely from the observation of the changed interference figures the nonlinear relation between deformation and tension can be derived for any value of tensile stress. (2) Also the change of the interference patterns due to temperature dependence of the elastic constants can now be predicted from the more generalized derivation. Since for ultrasonics the change of the elastic behavior is very sensitive to temperature, the pattern behavior near the melting point should give, according to Brillouin, some information concerning the melting process.

48. Determination of the Nature of a Light Source from Wide-Angle Interference Experiments. O. HALPERN AND F. W. DOERMANN, *New York University.*—It has previously[1] been shown that wide-angle interference phenomena can be used to determine the nature of (electric and magnetic) multipoles which make up the light source. The interference pattern was found to depend in a characteristic matter on the geometrical arrangement, the optical properties of the mirrors used and the nature of the light source. Applying these considerations to a wide-angle interference experiment performed by Selenyi[2] the authors were able to determine the active centers in the fluorescence substance which served as source. The polarization properties of the pattern do not permit to decide whether the source consists of electric dipoles or magnetic quadropoles (which latter can, of course, be ruled out by other considerations). The dependence of the pattern on the angle of divergence of the two primary beams clearly shows that the source consists of electrical dipoles.

[1] O. Halpern and F. W. Doermann, Phys. Rev. **52**, 937 (1937); F. W. Doermann, Phys. Rev. **53**, 420 (1938).
[2] P. Selenyi, Zeits. f. Physik **108**, 401 (1938).

49. Measurement of X-Ray Production in the Range 0.8 to 2.0 Million Volts. L. C. VAN ATTA AND D. L. NORTHRUP, *Massachusetts Institute of Technology.*—Some preliminary focusing tests with an electron beam have been made in the accelerating tube of the Massachusetts Institute of Technology electrostatic generator in its new location in Cambridge. In the course of these tests it has been possible to make some measurements on x-ray intensity as a function of angle, absorber and voltage in the range 0.8 to 2.0 mv. The x-ray intensity in the forward direction was found to increase approximately as the 5/2 power of the voltage while the concentration in the forward direction increased as would be expected. Absorption coefficients were measured for 1.0, 1.5 and 2.0 mv with lead thicknesses up to 2.5 cm. Intensity measurements were made with a Victoreen condenser type *r*-meter. The results are presented primarily because of their possible usefulness to those considering the installation of high voltage x-ray equipment.

50. The Uniqueness of an X-Ray Crystal Analysis. A. L. PATTERSON, *Bryn Mawr College.*—It has long been known that the essential problem of x-ray crystal analysis lies in the determination of the phases to be allotted to the quantities $F(hkl)$ whose absolute values can be obtained from x-ray intensity measurements. These quantities when given appropriate phases form the Fourier coefficients for the distribution of electron density in the crystal. A Fourier series whose coefficients are the measured quantities $|F(hkl)|^2$ has been used in x-ray analysis to give a direct determination of interatomic distances in crystals. Langmuir and Wrinch[1] have suggested that if the positions of the peaks in the F^2 series are known, the structure is uniquely determined. In the present paper it is shown that if the peaks in the F^2 series can be resolved, the structure determination can be made unique, except for the fundamental ambiguity of a center of symmetry. The proof depends on a knowledge of the atoms which compose the crystal and the demonstration that there is only one way in which a given set of atoms can produce a given F^2 series. A unique determination depends on the identification of the peaks of the F^2 series, and examples are presented which suggest that caution must be exercised in attempting to ascribe uniqueness to the interpretation of the structure of complex crystals.

[1] I. Langmuir and D. M. Wrinch, Nature **142**, 581 (1938).

51. A General Equation of State: Equations for Ammonia and Steam. J. L. FINCK, *New York, New York.*—In a published paper,* the writer has considered the possibility of enlarging the scope of thermodynamic systems by including metastable as well as the ordinary stable states. To do so, he has shown that it is necessary to consider p, v, T as three independent variables for a system in gaseous or liquid-vapor state. On this basis many phenomena can be explained very simply. In continuing this line of thought, the writer has been able to develop a general, explicit equation of state which may apply to a single gaseous phase, or a liquid-vapor system, where there is a single type of transformation. For the entropy η, and the three independent variables p, v, T, the equation is $\eta = a + bv + cp + dpv + (e + fv + gp + hpv) \ln T$. The latent heat of transformation is $\lambda_{p,T} = T(v_2 - v_1)(\partial\eta/\partial v)_{p,T} = T(v_2 - v_1)[b + dp + (f + hp) \ln T]$. Using the most recent ammonia and steam tables, the following values of the constants have been found. (η, p, v, T are in British units.)

	Ammonia		*Steam*	
	Liquid-vapor	Superheated	Liquid-vapor	Superheated
a	−6.3238	−31.4922	−6.1496	+0.8445
b	−0.6660	+ 0.12586	−0.4308	−0.005090
c	$+0.0_3$3982	− 0.07790	$+0.0_3$1059	-0.001210
d	+0.03280	− 0.09284	+0.02659	$-0.0_3$4551
e	+1.0469	+ 6.6863	+0.9924	+0.12487
f	+0.11292	− 0.01886	+0.06808	$+0.0_3$8938
g	$-0.0_4$6312	+ 0.01118	$-0.0_4$1496	$+0.0_3$1446
h	−0.004761	+ 0.01046	−0.003639	$+0.0_4$9145

These equations check the experimental data over the entire saturation dome, in most cases, to much better than one percent. In the superheated regions the agreement is of the order of three to five percent over the entire pressure and temperature ranges given in the tables.

* J. L. Finck, J. Frank. Inst. **225**, 411–435 (1938).

52. Probability of *K* Ionization of Nickel by Cathode Rays. D. L. WEBSTER, *Stanford University;* L. T. POCKMAN, *Cornell University;* K. HARWORTH AND PAUL KIRKPATRICK, *Stanford University.*—The probability of K ionization of nickel by cathode-ray bombardment has been experimentally determined in arbitrary units as a function of cathode-ray energy in a range extending from two to twenty-two times the K ionization energy ($V_K = 8320$ volts) by measuring the dependence of the $K\alpha$ line intensity from thin nickel targets upon tube voltage. Only small theoretical corrections need be applied to the original data. The targets ranged in thickness from 10^{-6} cm to $2 \cdot 10^{-5}$ cm and were free except for a backing of cellulose acetate approximately 10^{-5} cm thick. A new technique has

been developed for making and mounting thin films of large area (10 cm²). A comparison of these data with the corresponding data from helium and silver makes possible a direct qualitative estimate of both the influence of relativity and the influence of nonhydrogenic fields on the probability of K ionization. Although these data agree only roughly with nonrelativistic quantum mechanical theories, they agree within experimental error with the relativistic theory of Soden for $V/V_k>4$ if theory and experiment are arbitrarily matched at $V/V_k=22$. For $V/V_k<4$, the theory falls below the experiment, in qualitative agreement with Soden's work on the limitation of the Born Approximation.

53. The Electronic Structure of Alloys. MILLARD F. MANNING, *University of Pittsburgh.*—Considerable progress has been made, particularly by Hume-Rothery, in the correlation and interpretation of the phonomena connected with solid solutions of metals. Except for the work of Jones, there have been few connections established between this work and the quantum-mechanical theory of metals. The case when the solvent is copper and the solute is one of the elements following it in the periodic table is the easiest to discuss. For this case the highest occupied levels around the copper atoms will be lower than highest levels corresponding to the solute atoms at the same atomic volume and crystal structure. This means that for dilute solid solutions the solute atoms will have a positive charge and the copper atoms will have a negative charge. This negative charge around the copper atoms accounts for the expansion of the lattice and for the lowering of the freezing point. The negative charge on the solute atoms accounts for a number of properties. In particular, it offers an explanation for the fact that the coefficient of diffusion of copper in copper cannot be found by extrapolation of the observed coefficients of diffusion in copper of the elements following copper in the periodic table.[1]

[1] J. Steigman, W. Shockley and F. C. Nix, Washington Meeting, December, 1938.

54. Inertial Mass. PETER FIREMAN, *Magnetic Pigment Company, Monmouth Junction, New Jersey.*—The question is raised as to the reality of inertial mass as a specific attribute of matter: Is there in the inertial force of a mass anything apart or beyond the force of gravitation? In the author's opinion, inertia is always a manifestation of gravitational force, at times more obvious and at times less obvious. Obvious instance: a body resists external force owing to its weight. Less obvious instance: a highly polished steel sphere is resting on a perfectly smooth plane. A push starts it rolling; it keeps moving indefinitely. Why? Resting on a point, it was in a state of unstable equilibrium. The push disturbed its equilibrium, depressed its center of gravity in the direction of the motion due to the push. The disturbance is kept up, the depression continues and there is nothing to restore the original balance. Consequently the sphere keeps rolling on and on.

55. Difference in Scope of Theoretical Physics and Pure Mathematics. JOSEPH T. O'CALLAHAN, S.J., *College of The Holy Cross.*—With the ever increasing importance of mathematics in the study of physics, there has been manifest in recent years a tendency to regard theoretical physics merely as a branch of mathematics. To oppose this tendency it is necessary to insist upon the difference in the scope of the two sciences. Briefly the difference is this: theoretical physics incorporates in the problem some actual physical data, whereas no physical data are incorporated in any pure mathematical problem. This difference is elaborated to show that mathematics, as such, merely requires compatibility of elements forming the concepts; while the constructs of physics require a further compatibility with some actually existing reality. A short reference to experimental physics shows that there are three entirely different types of "law" involved, characteristic respectively of experimental physics, theoretical physics and pure mathematics. The example of the inverse square law of attraction is used to concretize the discussion.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 329

56. A Re-evaluation of the Atomic Constants. FRANK G. DUNNINGTON, *Rutgers University.*—The experimental work on all significant determinations of the atomic constants e, m and h has been reexamined and the results recalculated with two changes: (1) all assumptions as to values of combinations of atomic constants have been eliminated so that the results given represent what the experiments actually yield and (2) a consistent set of auxiliary constants has been used throughout. A Birge-Bond diagram will be given to present the results graphically and illustrate clearly the discrepancy. A least squares solution of these results has been made *without* using the Rydberg formula. The results are:

$$e=(4.8025\pm0.0007)\times10^{-10}\text{ e.s.u.},$$
$$m=(9.1073\pm0.0024)\times10^{-28}\text{ g},$$
$$h=(6.6133\pm0.0034)\times10^{-27}\text{ erg}\cdot\text{sec.},$$
$$e/m_0=(1.7590\pm0.0004)\times10^{7}\text{ e.m.u.},$$
$$h/e=(1.3771\pm0.0007)\times10^{-17}\text{ e.s.u.}$$

As to where the discrepancy originates, this solution together with an analysis of each type of measurement as to the fundamental laws involved indicates that either: (1) the existing body of experimental results is substantially correct and the Rydberg formula is in error, or (2) the Rydberg formula is correct and all the measurements of h/e and the radiation constants are in error, the error being

in some cases presumably experimental, and in other cases in the theory involved.

57. Absorption Spectrum of Heavy Benzene at 2730–2250A. H. SPONER, *Duke University.*—The absorption spectrum of C_6D_6[1] at 2730–2250A was photographed in the first order of a three-m grating spectrograph. As in C_6H_6 the spectrum consists of a number of series with bands progressing in intervals of 878 cm^{-1} (totally symmetrical frequency in the upper state), each interval containing a progression with 140-cm^{-1} spacing. The whole system corresponds to a forbidden electronic transition $^1A_{1g} \rightarrow {}^1B_{2u}$ made allowed by the interacting twofold degenerate vibrations of symmetry $E_g{}^+$. In agreement with this the first bands of the two major series represent vibrational transitions $0 \rightarrow 497$ and $579 \rightarrow 0$, the 579 and 497 cm^{-1} being carbon frequencies of symmetry $E_g{}^+$ in the ground and excited states, respectively. This conclusion was drawn from the fact that the distance between the above-mentioned two bands is $38789 - 37713 = 1076 = 579 + 497$ and from the occurrence of other progressions displaced from the main series by 82 cm^{-1} toward long waves, thus indicating transitions $579 \rightarrow 2 \times 497$ and $2 \times 579 \rightarrow 497$. The frequency difference of 140 cm^{-1} is considered as an $n-n$ transition of the carbon $E_u{}^+$ vibration (in analogy to Kistiakowsky's and Solomon's explanation of the 160 cm^{-1} frequency difference in C_6H_6). Plausible interpretations can be given for other progressions. The analysis is in agreement with the one proposed for light benzene.[2]

[1] I am much obliged to Professor D. H. Andrews for lending me the heavy benzene.
[2] To be published shortly in cooperation with G. Nordheim, A. L. Sklar and E. Teller.

58. Further Studies on the Infra-Red Absorption Spectra of the Fatty Acids. R. C. HERMAN AND R. HOFSTADTER, *Princeton University.*—The monomer and dimer spectra of two more acetic acids, CD_3COOH and CD_3COOD, as well as light and heavy propionic acids, C_2H_5COOH and C_2H_5COOD, have been obtained with a rocksalt spectrometer. The wave numbers of the principal bands in the monomer spectrum of CD_3COOH are: 3640, 2225, 1760, 1335, 1215, 1162, 1065, 925, 820, 796 cm^{-1}. Those in CD_3COOD are: 2660, 2270, 1760, 1280, 1160, 1060, 1000, 925, 812, 785 cm^{-1}. Although it has not been possible to make a complete assignment of bands, certain regularities have been observed in the monomers of the four acetic acids: CH_3COOH, CH_3COOD,[1] CD_3COOH, CD_3COOD. These will be discussed. The heat or association of heavy propionic acid has been found by using a method previously described.[1] The results of a single determination give a value of 6400 calories per bond per mole.

[1] R. C. Herman and R. Hofstadter, J. Chem. Phys. **6**, 534 (1938).

59. The Infra-Red Absorption Spectrum of Phenol Vapor. V. WILLIAMS, R. C. HERMAN AND R. HOFSTADTER, *Princeton University.*—The absorption of the single molecules of phenol has been examined in the infra-red from 1μ to 13μ with a rocksalt spectrometer. The spectrum of the vapor was obtained at 93°C and 164°C at pressures of 14 mm and 19 mm, respectively. The regions from 2.3μ (4350 cm^{-1}) to 3.5μ (2860 cm^{-1}) and from 9μ (1111 cm^{-1}) to 12μ (850 cm^{-1}) were repeated at higher pressures (about 180 mm) in order to bring out weak bands. Our absorption curves do not show the association bands near 3μ (3333 cm^{-1}) found in solid and liquid phenol and in solutions of phenol in CCl_4,[1] but do show the free O–H band at 2.7μ (3705 cm^{-1}). This indicates that we have obtained the monomer spectrum. We find a sharp band at 8μ (1250 cm^{-1}) and a relatively broad band at 8.5μ (1176 cm^{-1}). The center of gravity of these two bands lies close to a band whose variations in position and intensity with temperature were studied by R. R. Brattain[2] with the same instrument. In this region of the spectrum of solid phenol, J. Lecomte[3] finds bands at about 8.4μ (1190 cm^{-1}) and 8.8μ (1137 cm^{-1}).

[1] J. J. Fox and A. E. Martin, Proc. Roy. Soc. London **162A**, 419 (1937).
[2] R. R. Brattain, J. Chem. Phys. **6**, 298 (1938).
[3] J. Lecomte, J. de phys. et rad. **8**, 489 (1937).

60. Accommodation Coefficients of Helium *vs.* Nickel. BARBARA G. RAINES, *Bryn Mawr College.*—The variation with temperature of the accommodation coefficient of helium against nickel was investigated in the range 90–369°K by measuring the heat losses of an "A" nickel wire at 90, 194, 273 and 369°K both in vacuum and in an atmosphere of spectroscopically pure helium which at equilibrium attained a pressure of the order of 10 dynes/cm^2. After flashing in vacuum, the nickel wire was allowed to come to equilibrium before the helium was introduced. The accommodation coefficient (a_0) for helium against gas-free nickel was determined by extrapolating the heat loss through the gas to zero time after its admission. Within the experimental error, a_0 was constant over the entire temperature range, the average of seven determinations being 0.067 ± 0.006. The mean values at the four temperatures do, however, show a slight increase with rising temperature, being 0.061, 0.066, 0.071 and 0.074 at 90, 194, 273 and 369°K, respectively. The equilibrium values (a_e) of the accommodation coefficient (attained after about four minutes) were found to be 0.51, 0.45, 0.36 and 0.33 at 90, 194, 273 and 369°K, respectively. The accommodation coefficients here reported have not been corrected for roughening of the surface of the wire due to heat treatment.

61. An Apparatus for Determining the Orientation of Crystals by X-Rays. F. E. HAWORTH, *Bell Telephone Laboratories, Inc.*—An apparatus has been developed in which orientations of single crystals, and the crystals in polycrystalline materials, can be studied with x-rays by rotating the specimen and moving a photographic film at the same time. The apparatus combines the best features of both the Weissenberg goniometer[1] and that of Dawson[2] by having the x-ray beam incident along the axis of a cylindrical film and thus recording a Debye-Scherrer circle instead of a layer line. The motion of the film and rotation of the specimen may be continuous or in steps. For motion in steps an automatic mechanism is used which exposes the film for a length of time controlled by an electric clock, and then moves the film and rotates the specimen an amount controlled by a revolution counter geared to

the motor. When the cylindrical film is flattened the Debye-Scherrer circles become straight lines and a transparent net with rectangular coordinates is used to measure the angles. The data are then easily plotted in stereographic projection.

[1] K. Weissenberg, Zeits. f. Physik **23**, 229 (1924).
[2] W. E. Dawson, Phil. Mag. **5**, 756 (1928).

62. An Investigation into the Gettering Powers of Various Metals for the Gases Hydrogen, Oxygen, Nitrogen, CO_2 and Air. LOUIS F. EHRKE AND CHARLES M. SLACK, *Westinghouse Electric & Manufacturing Company.*—Measurements of the "gettering" or clean-up ability of aluminum, magnesium, thorium, uranium, misch metal, zirconium and barium for the common gases were made. In most cases the measurements were quantitative and represent gettering powers unassisted by an electric discharge or other source of ions. The effect of temperature conditions on the gettering and keeping properties of several of the getters is given. The superior gettering powers of the diffuse layers produced by vaporizing the getters in the presence of a gas, as compared to those of the bright getter deposits produced in a high vacuum, were confirmed. Barium and misch metal were found to be the most active of the materials tried, and the convenient forms in which barium is now commercially obtainable would seem to make it first choice for most work, though it is not effective in the presence of Hg vapor. Magnesium and aluminum showed little activity without the presence of a discharge. Thorium and uranium showed considerable activity for H_2 and O_2, but the high temperatures needed for flashing make them rather inconvenient to use.

63. Thermal Conductance of Metallic Contacts. C. STARR AND R. B. JACOBS, *Massachusetts Institute of Technology.*—In cryogenic apparatus, the thermal conductance between two clean metallic surfaces, in contact in a vacuum, is sometimes of importance. Such contacts may be employed for thermal switching purposes, and must be free of grease in order to operate at low temperatures. The properties of clean gold, silver and copper contacts, operating in vacuum, were studied at room and liquid nitrogen temperatures as a function of contact pressure up to three kg/cm^2. The thermal conductance of the contacts was found to increase with increasing contact pressure; the relationship was linear for copper only. The flatter the contact surfaces, the better was the conductance. At room temperatures, gold and silver were both equally better than copper, but at liquid nitrogen temperatures the order of merit was silver, gold, copper. Copper and gold grow progressively worse with time at low temperatures, perhaps due to adsorption phenomena. Silver did not exhibit this behavior, and as its contact conductance is least affected by temperature, it is the logical choice as a thermal contact material for low temperature work.

64. Determination of the Radon Content of the Spring Waters of Fairmount Park. J. LLOYD BOHN AND FRANCIS H. NADIG, *Temple University.*—Fairmount Park has an area of over 3000 acres within the city limits of Philadelphia, and has numerous springs which are the subject of this investigation. Of 12 springs already determined the values run from 2×10^{-10} to 35×10^{-10} curies per liter of water. Some of these values are rather high for springs in the United States and Canada[1] except those near known radium deposits. The more active springs issue from an early Cambrian formation while the less active ones issue from a Precambrian formation known as Wissahickon gneiss. Data on the radon content of tap and river waters and on the radium content of some of these waters will be included.

[1] Bulletin of the National Research Council on Radioactivity, Number 51, by A. F. Kovarik and L. W. McKeehan.

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Millman, S.—see Kusch, P.
Montgomery, C. G. and D. D. Montgomery—No. 22
Montgomery, D. D.—see Montgomery, C. G.
Moore, G. E., R. C. Garth and H. W. Webb—No. 29
—— see Garth, R. C.
Murray, R. T. K.—see Alter, B. E. K.

Nadig, Francis H.—see Bohn, J. Lloyd
Nielsen, W. M.—No. 19
Northrup, D. L.—see Van Atta, L. C.

O'Brien, Brian—No. 14
O'Callahan, Joseph T., S.J.—No. 55

Patterson, A. L.—No. 50
Peck, Mahlon F.—see Hector, L. G.
Pockman, L. T.—see Webster, D. L.

Raines, Barbara G.—No. 60
Renzetti, Nicholas A.—see Hamilton, Donald R.
Rosen, N.—No. 46
Rudnik, P.—see Ingersoll, L. R.

Schwinger, Julian—see Hamermesh, Morton
Scott, R. B.—see Brickwedde, F. G.
Seely, S., W. H. Zinn and V. W. Cohen—No. 39
Simon, R.—see Watson. W. W.
Slack, Charles M.—see Ehrke, Louis F.
Slack, F. G.—see Ingersoll, L. R.
Sponer, H.—No. 57
Starr, C. and R. B. Jacobs—No. 63
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Tonks, L.—No. 11
Trump, J. G. and R. J. Van de Graaff—No. 24
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Valley, G. E.—see Hill, J. E.
Van Atta, L. C. and D. L. Northrup—No. 49
Van de Graaff, R. J.—see Trump, J. G.
Van Vleck, J. H.—No. 9
—— see Weiss, P. R.

Watson, W. W. and R. Simon—No. 30
Way, Katharine—No. 33
Webb, H. W.—see Garth, R. C.
—— see Moore, G. E.
Webster, D. L., L. T. Pockman, K. Harworth and P. Kirkpatrick—No. 52
Weiss, P. R. and J. H. Van Vleck—No. 10
Weisskopf, Viktor—No. 35
White, T. N., L. Marinelli and G. Failla—No. 25
Williams, H. J. and R. M. Bozorth—No. 7
Williams, V., R. C. Herman and R. Hofstadter—No. 59

Zinn, W. H.—see Seely, S.

THE OPTICAL SOCIETY OF AMERICA

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PROGRAM

FRIDAY, FEBRUARY 24, AT 9:30 A.M.

Room 428

Contributed Papers

1. Spectroradiography with the Cathode Ray Tube. R. L. GRAHAM AND R. H. MÜLLER, *New York University*. (15 minutes.)

The feasibility of instantaneous spectrophotometry has been demonstrated by the authors.[1] The extension and refinement of the basic idea has been resolved into the optical and electronic requirements for spectrophotometry, densitometry, filter photometry and the evaluation of emission spectra, typical examples of which will be shown. In general the spectrum which is to be measured is passed rapidly before a narrow slit by means of a synchronously driven Fresnel prism. A photo-cell placed behind the slit measures the intensity. The photo-cell feeds an appropriate video amplifier driving the vertical deflector plates of the oscillograph. The horizontal component (wave-length scale) is furnished by a linear sweep circuit synchronized by the same beam. The stationary pattern is in all respects similar to that obtained in the conventional manner. The automatic reduction to an equal-energy spectrum has not been completely solved, but some degree of compensation for source distribution is achieved by the choice of an appropriate photo-cell cathode. This leaves a residual limitation comparable to that encountered in photographic photometry. The performance may be greatly improved by utilizing the higher signal to noise ratio of electron multiplier tubes, and the complete elimination of mechanical scanning by means of image dissector tubes, when these devices become more generally available. Contemporary progress in television indicates that these methods may soon become superior to the existing techniques of spectrometry. With the few present restrictions the method has been very useful in studying the absorption in fugitive chemical and biological systems.

[1] R. H. Müller and R. L. Garman, Mikroc hemie 21, 302 (1937).

2. The First Spectrum of Tin.* WILLIAM F. MEGGERS *National Bureau of Standards*. (15 minutes.)

The first regularities in the arc spectrum of tin, found by Kayser and Runge in 1894, have been extended and interpreted during the last 20 years but even now only the terms given by the $5p^2$, $5p6s$, and $5p6d$ electron configurations are well established. Miscellaneous other levels have been variously interpreted but many of these are fictitious because of inaccurate wave-length data. The spectrum has been remeasured from 1,699.40 to 12,536.7A, and the maximum deviation of calculated and observed wave numbers has been reduced from 12 to 0.2 cm^{-1}. Analysis yields all the terms arising from $5p7s$, $5p6p$, $5p7p$, $5p6d$, and other levels probably representing $5p8s$, $5p9s$, $5p10s$, $5p11s$, $5p7d$, $5p8d$, and $5p4f$.

* The present paper will appear in full in *Journal of Research of the National Bureau of Standards*.

3. Behavior of an Interferometer in a Gravitational Field.* HERBERT E. IVES, *Bell Telephone Laboratories*. (25 minutes.)

A discussion of the consequences of the two assumptions: (1) That a Michelson interferometer gives identical results at any place in a gravitational field. (2) That the effect of a gravitational field on the dimensions and "clock" of an interferometer is the same as an acceleration [Einstein's equivalence principle]. From the second assumption it follows that the interval between clock "ticks" (τ') for a clock stationary in the gravitational field will be increased according to the relation $\tau' = \tau/\sqrt{\gamma}$ where τ is the interval in the absence of the field; and that the length of a stationary interferometer arm, lying in the radial direction of a spherically symmetrical gravitational field, will be decreased according to the relation $L' = L\sqrt{\gamma}$ where L is the length

in the absence of the field or of motion [undistorted length]. $\sqrt{\gamma}$ is some function of the radial distance R from the attracting center of mass M, which becomes unity when R is infinite. It then follows at once from assumption (1), on considering a *stationary* interferometer, that the velocity of light in the radial direction must be $c\gamma$, and in the transverse direction $c\sqrt{\gamma}$. Assumptions (1) and (2), with the consequence just deduced, thus call for a reduction in frequency for a natural clock in a gravitational field, and for the bending of the front of a light wave in passing near a large mass.

It is next pointed out that the "line element," s, $(=(c^2t^2-x^2-y^2-z^2)^{\frac{1}{2}})$ is actually the expression for (twice) the undistorted length of an arm of an interferometer which when in motion gives, owing to the Fitzgerald contraction, unchanged indications. The undistorted length of the interferometer arm moving in a gravitational field and experiencing the Fitzgerald contraction is similarly shown, in accordance with the above assumptions, to be, in polar coordinates, in a plane, $L=\frac{1}{2}(c^2t^2\gamma-R^2\theta^2-R^2/\gamma)^{\frac{1}{2}}$.

Let γ be assumed by analogy with the contractions due to motion to have the form $1-w^2/c^2$. If now w is the velocity of a freely falling particle in a Newtonian gravitational field, w^2 may be expressed as GM/R, where G is the Newtonian gravitational constant and M the mass of the attracting body. This gives $\gamma=1-GM/Rc^2$, and we get $s=[c^2t^2(1-GM/Rc^2)-R^2\theta^2-R^2/(1-GM/Rc^2)]^{\frac{1}{2}}$, which is the Schwarzschild expression of general relativity.

* The present paper will appear in full in the *Journal of the Optical Society of America*.

4. Calculation of the Luminous Efficiency of Ionized Cesium Vapor. FRED L. MOHLER, *National Bureau of Standards*. (15 minutes.)

In a discharge at high pressure and high current density most of the radiant energy is in the continuous recombination spectrum. On the basis of experimental data on cesium[1] it is possible to predict the characteristics of a discharge for pressures beyond the range of experiment. There is nearly temperature equilibrium and the degree of ionization for a given temperature and pressure is given by the Saha equation. The emissivity of a column of vapor of diameter d is computed from experimental and theoretical data on transition probabilities, and the radiant flux is equal to the flux of a blackbody at the given temperature times the emissivity. Graphical integration of plots of radiant flux and luminous flux as functions of frequency gives the relative luminous efficiency. Values as high as 180 lumens per watt are obtained. For sufficiently high pressures the power input is nearly all radiated and the over all efficiency nearly equal to the relative efficiency. The resistivity is a known function of the temperature so that the current and voltage required to maintain a given temperature in a tube of diameter d can be calculated. Nearly maximum efficiency is obtained for a range of conditions centering around $d=1$ cm, $T=6000°$K, $p=176$ mm of mercury. The brightness temperature is about 5400°K and the color temperature 3700°K. This requires a current of 300 amperes and a gradient of 22 volts per cm. At 760 mm and 6000°K the brightness and color are nearly the same as a blackbody at that temperature and the efficiency is 100 lumens per watt.

[1] Mohler, Nat. Bur. Standards J. Research **21**, 697 and 893 (1938).

FRIDAY, FEBRUARY 24, AT 2:00 P.M.

Room 428

5. Comparative Effect of Cobra Venom and Opiates on Acuity and Field of Vision.* DAVID I. MACHT AND MOSES B. MACHT, *Hynson, Westcott & Dunning, Inc.* (15 minutes.)

The senior author has been engaged for five years in the pharmacological and therapeutic study of cobra venom. This drug is an efficient analgesic often replacing morphine for relief of intractable pain. Studies were made in which cobra venom and various opiates were compared in regard to their by-effects and pain-relieving efficiency. Experiments made on various psychological functions, particularly on vision, were of special interest. A comparison was made of cobra venom with morphine, codeine, heroin, dilaudid and pantopon and certain nonnarcotic analgesics on a group of healthy normal individuals to determine the influence of the respective drugs on the acuity and field of vision. It was found that neither morphine nor cobra venom impaired acuity of vision as tested by standard reading charts. On the contrary, in more than half the subjects, injection of cobra venom definitely increased the acuity of vision. Cobra venom did not alter size of pupil whereas morphine, as usual, produced myosis. The field of vision for white, blue, red and green, as studied with the aid of a perimeter, was definitely narrowed or contracted after administration of morphine, codeine, heroin, dilaudid and pantopon. Cobra venom, on the other hand, in such therapeutic doses as are employed for relief of pain, definitely widened the field of vision. This effect was found to be greatest for red and green colors. Analgesics of the nonnarcotic type, such as aspirin, various antipyretics, barbitals, usually depressed and narrowed the field of vision.

* The present paper will appear in full in the *Journal of the Optical Society of America*.

[1] Macht, Isaacs and Greenberg, Proc. Soc. Exper. Med. **15**, 47 (1917).
[2] Macht, Proc. Nat. Acad. Sci. **22**, 61 (1936).
[3] Macht, M. Rec. **144**, 537 (1936).
[4] Macht, Trans. Am. Therap. Soc. **45** (1937).
[5] Macht, Ann. Int. Med. **11**, 1824 (1938).

6. Facts and Theory of Color Blindness.* A. H. HOLWAY AND M. J. ZIGLER, *Wellesley College*. (25 minutes.)

Various attempts have been made to classify color-blind individuals in terms of the general parameters possessed by visibility curves. The available curves for protanopes (red

blind), deuteranopes (green blind), and tritanopes (blue blind) are usually subjected to direct comparison and the existing departures from the normal function are noted. The observed differences are then used as a basis for the quantitative designation of the three types of color deficiency. This procedure assumes that the samples treated are representative of the total population under scrutiny. A consideration of the neurophysiology of color perception, however, reveals in striking fashion that the cases thus far studied are not representative. The available data imply the existence of three type-curves,—whereas dichromats as a general class can be shown theoretically to require nine (instead of three) typical visibility curves as limiting cases. The major (quantitative) properties of these curves are specified graphically. These nine types and their special characteristics are consistent with present-day understanding of normal color vision; they enable examiners to classify anomalous as well as better known cases, and hence are to be recommended as standards of reference for the study and diagnosis of color deficiencies.

* The present paper will appear in full in the *Journal of General Psychology*. .

7. An Experimental Determination of the Spectral Components of Psychologically Unique Red.* FORREST L. DIMMICK AND MARGARET R. HUBBARD, *Hobart College*. (15 minutes.)

In a preceding paper[1] we presented the results of an experimental determination of the spectral location of the psychologically unique yellow, green and blue, namely, 583$\mu\mu$, 515$\mu\mu$, and 477$\mu\mu$, respectively. There is general agreement in the literature that extreme spectral red is somewhat yellowish. Our experiment pointed to the correctness of this general observation and we undertook to ascertain the amount of our unique blue (477$\mu\mu$) that must be added to spectral red (635$\mu\mu$) to give a red that appears neither yellowish nor bluish. Special apparatus was devised for the problem. Five observers who had had the training of the previous experiment gave values lying close to 493$\mu\mu$c for unique red. With the apparatus used in this experiment, we can measure the relative resemblances of a color to any two of the unique hues, to black or white, and to gray, which correspond, respectively, to the conventional hue, brilliance and saturation. These resemblances are expressed in the formula $(R \text{ or } G)+(B \text{ or } Y)+(Bk \text{ or } W)+Gy=C_x$. Dr. Judd has derived transformation equations for us by which we can convert the 4-color equation into tristimulus values and conversely. The utility of the 4-color equation lies in the fact that it gives an immediate indication of the appearance of the color in question.

* The present paper will appear in full in the *American Journal of Psychology*.

[1] Margaret R. Hubbard and Forrest L. Dimmick, "An Experimental Determination of the Spectral Location of Psychologically Unique Yellow, Green and Blue," Abstract, Program of the 23rd Meeting of the O. S. A.

8. Hue, Saturation and Lightness of Surface Colors with Chromatic Illumination. DEANE B. JUDD, *National Bureau of Standards*. (20 minutes.)

Preliminary data on this subject were presented[1] in 1934 together with a discussion of the regularities exhibited by them. It was noted that our estimates of lightness can be satisfactorily represented by the formula due to Adams and Cobb[2] and that there was prospect of discovering successful empiric formulas for hue and saturation. With the aid of extensive further data obtained by Helson[3, 4] such formulas have been found. These formulas identify hue with direction of the vector on the color triangle[5] extending from the point representing an achromatic color to that representing the surface color; and they identify saturation with the length of this vector. The point (r_n, g_n, b_n) representing an achromatic color serves to define the chromatic state of the observer; depending upon the particular sample fixated by the observer, this point wanders about within the region of the triangle near the point (r_0, g_0, b_0) representing the average of the visual field. These variations have been found to correspond primarily with the relation of the apparent reflectance, A, of the surface fixated to the adaptation reflectance, A'.[4] A secondary but definite dependence has also been found with amount of illumination, I, in footcandles. Both of these factors are taken into account in the empiric formula:

$$r_n = r_0 - D_0[0.1L'(1+10b_0)(r_0-0.360) - 0.017b_0A'(L')\log_{10} 2000I],$$

$$g_n = g_0 - D_0[0.1L'(1+10b_0)(g-0.300) - 0.030],$$

$$b_n = 1 - r_n - g_n,$$

where $D_0^2 \equiv (r_0-0.490)^2+(g_0-0.470)^2+(b_0-0.090)^2$,

(0.490, 0.470, 0.090) being the point representing daylight, and $L' \equiv 10A/(A+A')-5$. This formula permits the hue-saturation vector to indicate correctly such apparently anomalous results as that reported by Helson[3] who found nonselective diffusing surfaces to yield red, green or gray colors under a red illuminant depending on whether their apparent reflectances are higher than, lower than, or equal to the adaptation reflectance. Comparisons of the preliminary observations with values of hue and saturation computed by this method generally show agreement within experimental uncertainty. Further adjustment of constants might possibly eliminate the few exceptions, but it is planned next to check the formulas against the extensive data assembled by Helson.[6]

[1] J. Opt. Soc. Am. **25**, 44 (1935).
[2] J. Exp. Psych. **5**, 39 (1922); J. Opt. Soc. Am. and Rev. Sci. Inst. **9**, 932 (1922).
[3] J. Opt. Soc. Am. **27**, 59 (1937).
[4] J. Exp. Psych. **23**, 439 (1938).
[5] J. Opt. Soc. Am. **25**, 24 (1935).
[6] See Paper No. 9 of this program.

9. Effects of Certain Variables on Hue, Lightness, and Saturation of Samples Having Identical Trilinear Coordinates. HARRY HELSON, *Bryn Mawr College*. (18 minutes.)

Two samples with identical trilinear coordinates[1] are often said to have the same hue. Observations with sample behind a small aperture in a black screen give reports agreeing in general with expectations from plot in color triangle. But if the front of the screen is illuminated with strongly chromatic light which, however, does not affect the sample behind the screen, contrast effect may render the aperture color achromatic or complementary in hue to the illumination, depending upon the brightness of the aperture color. Similar effects can be obtained with free

viewing of sample by the use of backgrounds of different reflectances.[2] Under these conditions position in color triangle is not a valid index of hue. The relation of sample to background reflectance and of both to 'adaptation reflectance' must be taken into account as determiners of hue as well as the factors now taken into account in the computation of trilinear coordinates. A weighted geometric mean reflectance proposed by Judd for adaptation reflectance has been found close to the facts. These changes in hue can be summarized thus: samples having reflectances above adaptation reflectance tend to take the hue of the illuminant while those below it tend to take the complementary hue. When samples are viewed in strongly chromatic illumination the relation between lightness and saturation differs from that obtained under the usual conditions. Lightnesses above adaptation lightness are accompanied by increasingly saturated colors and those below adaptation lightness have increasingly saturated complementary colors. Instead of maximum contrast effects with samples near background lightness we have a minimum at this level. Hence the classical accounts of the lightness-saturation and lightness-contrast relations do not fit the facts found in strongly chromatic illuminations but a reformulation of the matter in terms of the principle given above seems to cover all the facts. Formulae devised by Judd[3] have been found to yield good approximations to the data under discussion.

[1] D. B. Judd, J. O. S. A. **23**, 359–374 (1933).
[2] H. Helson, J. Exp. Psych. **23**, 439–476 (1938).
[3] See Paper No. 8 in this program.

SATURDAY MORNING AT 10:00 O'CLOCK

National Broadcasting Company

RCA Building, 30 Rockefeller Plaza
Studio 3A

Joint Session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council

SYMPOSIUM ON TELEVISION

Invited Papers

1. **Electron Optics as Applied in Television Systems.** V. K. ZWORYKIN, *RCA Manufacturing Company*
2. **Application of Electron Multipliers to Voltage Amplification.** P. T. FARNSWORTH, *Farnsworth Television, Incorporated*
3. **Demonstrations in Television.** A. F. VAN DYCK, *Radio Corporation of America*

Cards of admission will be required for this symposium and may be obtained by members of the societies without charge at the registration desk in Pupin Physics Laboratories on Friday.

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PROGRAM

All sessions to be held at the auditorium of the Electrical and Gas Association of New York, 480 Lexington Avenue, New York City.

COMMITTEE ON ARRANGEMENTS:

M. REA PAUL, *Chairman*
WILLIAM F. LITTLE
S. M. NEWHALL, *afternoon program*
R. G. SLAUER, *evening program*
CARL E. FOSS, *exhibits*

THURSDAY, FEBRUARY 23, AT 9:30 A.M.

Business Session

Reports of Officers, News Letter Editor, Committee Chairmen, with recommendations for Council action on several important color problems.

Reports of delegates representing each member group will be requested:

American Association of Textile Chemists and Colorists, W. M. Scott
American Ceramic Society, V. H. Remington
American Psychological Association, F. L. Dimmick
American Society for Testing Materials, M. R. Paul
Illuminating Engineering Society, H. P. Gage
National Formulary, American Pharmaceutical Association, D. C. Beach
Optical Society of America, I. H. Godlove
Technical Association of the Pulp and Paper Industry, J. L. Parsons
Textile Color Card Association of U. S. Inc., M. H. Rorke
U. S. Pharmacopoeial Convention, H. C. Muldoon
Individual Member Group, Le Grand H. Hardy

THURSDAY, FEBRUARY 23, AT 2:00 P.M.

TECHNICAL SESSION ON COLOR TOLERANCES

Jointly Sponsored by the Inter-Society Color Council and the American Psychological Association

Chairman: Forrest Lee Dimmick

Invited Papers

1. The Physics of Color Tolerance. DEANE B. JUDD, *National Bureau of Standards.* (8 minutes.)—The physical specification of a reflecting sample requisite to determine its color is the spectrophotometric curve. The spectrophotometer not only gives more complete and fundamental information about such a sample than can be determined by direct visual inspection, but also is generally more sensitive than the human eye,[1] and the results are reproducible.[2] There are, however, pairs of samples which have the same daylight colors which do not have the same spectrophotometric curves.[3] It is, therefore, necessary to take into account some of the properties of the human visual mechanism evaluated by psychophysical methods. These properties are expressed in the response curves of the eye defining the groups of physically dissimilar lights which look alike to the average normal observer. By using these response curves, together with the spectral energy distribution of an illuminant and the spectrophotometric

curve of the sample, it is possible to calculate a color specification for the sample. A standard coordinate system for colorimetry has been adopted by an international standardizing body.[4] Graphical, arithmetical, mechanical, and electrical short-cuts have been devised for the reduction of time taken up by the computations.[5] The color specification most commonly takes the form of daylight reflectance, R, of the sample and two trichromatic coefficients, x and y, which indicate chromaticity; reflectance and chromaticity indices taken together make up the color specification. Color differences are evaluated by differences in R, x, and y. A physical quantity can only be defined in terms of the operations which have to be carried out to evaluate it.[6] The above-mentioned operations which lead to differences in R, x, and y are, therefore, the definition of what is meant physically by color difference; this is an unambiguous definition, and by it the color difference between any two samples may be unambiguously evaluated. However, these evaluations often do not agree with estimates of the color differences obtained by direct visual inspection of the samples. Many attempts[7] have been made to devise a series of operations to serve as an alternate definition of color which would yield this agreement, but none of the suggested methods has yet been generally accepted. There is some prospect that a system analogous to the present standard coordinate system will be devised within a few years to give color spacing in accord with perception. The chief obstacle is the paucity of information on the perceptibility of color differences. This information has to be evaluated by psychophysical methods. The physicist awaits the completion of this information with interest[8] because of its bearing on color tolerance, but in the meantime finds many color tolerance problems in which questions of perceptibility are overshadowed by questions of permanence of materials and possible degree of manufacturing control. To these latter questions the present coordinate system is perfectly applicable.

[1] R. D. Nutting, "Detection of Small Color Differences in Dyed Textiles," J. Opt. Soc. Am. **24**, 135 (1934).
[2] K. S. Gibson and H. J. Keegan, "Calibration and Operation of the General Electric Recording Spectrophotometer of the National Bureau of Standards," J. Opt. Soc. Am. **28**, 372 (1938).
[3] *Color as Light*, Monograph No. 2 of a Series on Color (The Research Laboratories, International Printing Ink Corp., New York, 1935). C. Bittinger, "Applications of Colors of Similar Appearance but Different in Spectral Composition," J. Opt. Soc. Am. and Rev. Sci. Inst. **10**, 292 (1925).
[4] D. B. Judd, "The 1931 I. C. I. Standard Observer and Coordinate System for Colorimetry," J. Opt. Soc. Am. **23**, 359 (1933).
[5] A. C. Hardy and O. W. Pineo, "Computation of Trichromatic Excitation Values by the Selected Ordinate Method," J. Opt. Soc. Am. **22**, 430 (1932). A. C. Hardy, *Handbook of Colorimetry* (Technology Press, Cambridge, Mass., 1936), pp. 49–87. J. Razek, "Electrical Device for the Determination of Trilinear Coordinates for the Razek-Mulder Color Analyzer," J. Opt. Soc. Am. **24**, 54 (1934). H. W. Swank and M. G. Mellon, "A Calculator for Obtaining Tristimulus Values from Spectrophotometric Data," J. Opt. Soc. Am. **27**, 414 (1937).
[6] P. W. Bridgman, *The Logic of Modern Physics* (Macmillan, 1927). A. C. Hardy, *Handbook of Colorimetry* (Technology Press, Cambridge, Mass., 1936), p. 1.
[7] D. B. Judd, "A Maxwell Triangle Yielding Uniform Chromaticity Scales," Nat. Bur. Stand. J. Research **14**, 41 (1935); "Estimation of Chromaticity Differences and Nearest Color Temperature on the Standard 1931 ICI Colorimetric Coordinate System," Nat. Bur. Stand. J. Research **17**, 771 (1936). R. H. Sinden, "A Further Search for the Ideal Color System, I. A New Mechanico-Graphical Method," J. Opt. Soc. Am. **27**, 124 (1937); "II. A Reconsideration of the Helmholtz Line Element," J. Opt. Soc. Am. **28**, 339 (1938). L. Silberstein, "Investigations on the Intrinsic Properties of the Color Domain," J. Opt. Soc. Am. **28**, 63 (1938). D. L. MacAdam, "Projective Transformations of I. C. I. Color Specifications," J. Opt. Soc. Am. **27**, 294 (1937).
[8] A. C. Hardy, "The Physical Basis of Color Measurement," J. App. Phys. **8**, 233 (1937).

2. The Psychophysics of Color Tolerance. EDWIN G. BORING, *Harvard University*. (30 minutes.)—There is definitely a psychophysical problem of color tolerance, since imperceptible differences must lie within the limits of perceptual tolerance and since the purpose of color is for the most part to be perceived. The *jnd* (just noticeable difference) is not a psychological measure of color because it varies from instant to instant. The *DL* (differential limen) is such a measure. It is the stimulus value for a difference which occurs with a given frequency.[1] This definition means that subliminal differences are often perceived (though never so often perceived as not) and that the strictest limit of tolerance would have to be subliminal. The *DL* is not a psychological or physiological quantum. Sensation may ultimately be limited by the quantal nature of physiological processes, but the physiological all-or-none processes are masked in the discriminatory process. Fundamentally, in spite of the *jnd*, sensation is a continuous function of stimulus.[2] Unfortunately the *DL* is an inconstant measure of sensation for the reason that the readiness of an observer to use the equality category in making judgments can not be accurately controlled.[3] The *DL* measures this readiness, which varies because the observer confuses equality with doubt. This confusion occurs in all scientific measurement, and is the reason why the essential judgment of *equality* always becomes a judgment of *not-different*. The way to avoid the difficulty is to eliminate the category of equality, as is habitually done in physical measurement where equality is considered to be a point of infinitesimal extension. If the equality category is abolished, the *DL* becomes zero but discriminatory sensitivity can still be measured by the semi-interquartile range or other measure of precision of the psychometric function. The observer judges only *greater* or *less*, and the difference represented by the 75-percentile is the measure of precision. This measure is more reliable than the *DL*. A sensory measure different from the *DL* is the sense-distance. For its determination there are four closely related procedures: (1) the method of equation ($AB=CD$); (2) the method of bisection ($AB=BC$); (3) the method of halving ($B=A/2$); and (4) the method of fractionation ($B=A/n$). The first two methods are the oldest, and are applicable to different situations. The third method is recent and has yielded valuable results. The relation between the sense-distance and the *DL* is sometimes, but not always, linear.[4] All *DL*'s are not necessarily equal sense-distances. This seeming paradox means really that different differences may occur with the same frequency, and the same differences may occur with different frequencies. Similarly, since sensation actually varies by discrete steps, the *jnd* may be large or small depending on the size of the discrete step by which the sensation varies. It seems likely that tolerance would more often be satisfactorily measured by sense-distance than by frequency of perceived difference. The ideal diagram in which tolerances could be plotted is a five-dimensional surface, plotted against wave-length, energy, hue, brightness and saturation, with any two coordinates determining the other three.[5] This surface would be known, if we had a family of equal-brightness contours plotted against wave-length and energy, with the separation between the brightness con-

tours made equal sense-distances, and if we had the corresponding families of functions for hue and for saturation.

[1] J. P. Guilford, Psychometric Methods, 187–200 (1936).
[2] E. B. Titchener, Experimental Psychology, II, ii (1905), pp. 146–149.
[3] J. P. Guilford, Psychometric Methods, 201–205 (1936); R. S. Woodworth, Experimental Psychology, 421–425 (1938).
[4] S. S. Stevens and H. Davis, *Hearing* (1938), pp. 76–81, 84–89, 95–97, 112–120, 147–152; D. B. Judd, "Saturation Scale for Yellow Colors," J. Opt. Soc. Am. **23**, 35–40 (1933).
[5] E. G. Boring, "Isochromatic Contours," Am. J. Psychol. **49**, 130–134 (1937); D. M. Purdy, "The Bezold-Brücke Phenomenon and Contours for Constant Hue," ibid. 313–315 (1937).

3. The Ratio Method in the Review of the Munsell Colors. SIDNEY M. NEWHALL,* *Johns Hopkins University.* (15 minutes.)—If the spacing of the Munsell system were ideal, it would provide for the psychological expression of color tolerances, but the system is known to contain various irregularities. The purpose of the review of the Munsell colors is to detect and correct errors of allocation in psychological color space. In the effort to achieve this purpose observers are viewing the Munsell charts and recording apparent irregularities in the spacing of the samples. This operation involves the application of a device which is related in principle to the classical psychophysical method of equal sense-distances and in practice to the more recent methods of rank order and single stimuli.[1] This is the ratio method and it consists in the estimation by direct impression of the ratio of unequal supraliminal sense-distances or intervals.[2] The recording of the estimate is by means of linear extents or numbers which seem to the observer to be in the ratio of the sense-magnitudes in question. The ratio method clearly applies to the important case in this review where a number of samples are supposed to differ by equal steps with respect to a given principal attribute such as saturation. The observer can compare each saturation interval between adjacent samples with a certain interval taken as standard, and record apparent departures from equality in a form of vector notation. Thus, in the case of each interval between samples an estimate can be secured of the ratio of its magnitude to that of the standard interval. As a preliminary to this estimate the method of relative order or ranking was often resorted to without special intent; for it is easier to decide which of two intervals is greater than to estimate how much greater. A variant of the method of single stimuli was also employed in a supplementary way because it is sometimes easier when making numerous comparisons to carry a subjective standard than to refer repeatedly to a perceptual one. After estimates have been recorded by numerous observers, representative values can be determined and employed in respacing those samples which appear to require it. A preliminary report on the respacing of saturation, which is based on data available last summer, has already been published.[3] Those results are interpreted as indicating that the present procedure will prove effective in testing the spacing and in eliminating any serious irregularities in all three attributes. Belief in the eventual availability of smoothed curves has already led to the development of a color tolerance formula for use in conjunction with them.[4] The ratio method has the advantage of yielding results relatively rapidly and it is already being applied in color tolerance determinations. Its use emphasizes, once again, the need for experimentation on the traditional problem of the equality of supraliminal differences corresponding to equal numbers of just noticeable differences.[5]

* Chairman: subcommittee on Review of Spacing of the Munsell Colors, Colorimetry Committee of O. S. A.
[1] J. P. Guilford, *Psychometric Methods* (McGraw-Hill, 1936), pp. 143–165, 205–206, 244–262.
[2] L. F. Richardson, "Quantitative Mental Estimates of Light and Colour," Brit. J. Psychol. **20**, 27–37 (1929). R. S. Maxwell, "The Quantitative Estimation of the Sensation of Colour," Brit. J. Psychol. **20**, 181–189 (1929). T. Smith, "The Quantitative Estimation of the Sensation of Colour," Brit. J. Psychol. **20**, 362–364 (1929). L. F. Richardson and R. S. Maxwell, "The Quantitative Mental Estimation of Hue, Brightness or Saturation," Brit. J. Psychol. **20**, 365–367 (1929). L. F. Richardson, "The Measurability of Sensations of Hue, Brightness or Saturation. Discussion on Vision," Phys. Soc. 112–116 (1932).
[3] D. Nickerson, *Use of ICI Tristimulus Values in Disk Colorimetry* (U. S. Department of Agriculture Prelim. Report, May 1938).
[4] D. Nickerson, "The Specification of Color Tolerances," Textile Res. **6**, 505–514 (1936).
[5] E. G. Boring, "A History of Experimental Psychology," Century, 280–281, 286–287 (1929).

Intermission—10 Minutes

4. Color Tolerances as Affected by Changes in Composition and Intensity of Illumination and Reflectance of Background. HARRY HELSON, *Bryn Mawr College.* (20 minutes.)—The hue, lightness, and saturation of any object depends upon a complex of conditions, chief of which are the spectral reflectance of sample and background, spectral distribution of energy in the illuminant, and state of the visual mechanism under the conditions of viewing. The question of color tolerances concerns not only the conditions under which two samples will be judged identical but also the conditions under which they will be judged as different and the kind of difference to be expected. Thus two samples which are judged as almost identical "reds" on black background may be described as red and purple-red on white background; or two samples which are reported achromatic in light of about 6500°K may be reported as red and blue-green in fairly homogeneous red light if they have high and low reflectances respectively. Certain general principles can be laid down which make it possible to take into account changes in color resulting from certain changes in conditions of viewing. Contrary to views commonly heard, changes in intensity of illumination have little effect on hue, lightness and saturation provided spectral composition is unchanged. Samples were found to be most saturated at a medium intensity (72 footcandles on the sample plane) and least saturated at the lowest intensity (1.4 footcandles). The average difference between best and poorest was about three-fourths of a saturation step on a ten-fold saturation scale. The two highest intensities were better than the two

lowest. The changes in composition of illuminant were of far greater importance. Observations made under fairly homogeneous illuminants (red, yellow, green and blue) bring out the effect of quality of illuminant on sample color: samples having reflectances above the adaptation reflectance (which is roughly the geometric mean reflectance of background and all sample reflectances) take on the hue of the illuminant, samples below this reflectance take the hue complementary to the illuminant hue, while samples near the adaptation reflectance tend to appear achromatic. This principle accounts for the tendency of illuminants to color samples, for example, sunlight which tinges light samples with yellow and makes dark samples bluish. On the other hand, due to the "constancy phenomenon" a good deal of homogeneous light can be added to white light without destroying recognition of sample color, though it will be contaminated with the color of the illuminant. Reflectance of background comes only second in importance to composition of the illuminant in which samples are viewed. Backgrounds of low reflectance (black) induce the hue of the illuminant, white backgrounds induce the complementary hue. Change in background is itself sufficient to cause a change in hue, lightness and saturation of practically all samples. The average increase in saturation of samples on black ground as against white ground was 1.21 saturation steps, on gray over white, 0.70 step, and on black over gray, 0.42 step. While the equilibrium or adaptation state of the eye tends to approximate backgrounds of medium reflectance (gray) and would therefore seem to be best, owing to the splitting effect of gray ground on samples which tend to lie both above and below it in reflectance, different colors are induced on the samples if the illuminant is not strictly a good "white"—the light ones take one color and the dark the complementary. In matching colors it is necessary, therefore, to take into account effects induced by illuminant and background which can alter the color qualities of samples being viewed. Typical results will be given which illustrate the various effects discussed in the paper.

5. Representation of Color Tolerances on the Chromaticity Diagram. DAVID L. MACADAM, *Eastman Kodak Company*. (20 minutes.)—The maximum acceptable variations of sample colors from a standard color for some definite use are called color tolerances. Color tolerances can be represented in any plane chromaticity diagram by a family of closed figures, each figure enclosing all of the acceptable chromaticities of samples having a specified brightness acceptably close to the brightness of the standard. There is no fundamental reason why any one trichromatic coordinate system should be preferred over all other such systems for the representation of color tolerances. Since the coordinate system adopted in 1931 by the International Commission on Illumination is widely used and is satisfactorily specified by name, it is used throughout this paper and is recommended for all representations of color tolerances.[1–4] Other coordinate systems have been proposed for the representation of color tolerances. These proposals are usually based on the belief that the representation of just noticeable color differences can be simplified by the use of some suitable coordinate system.[5–8] This possibility requires further investigation. The relative magnitudes of the just noticeable color differences in different directions from a standard color, and for widely different standard colors, may depend seriously on conditions of observation such as the size and brightness of the test field and on the distribution of color in the surrounding field. Therefore, even if just noticeable color differences can be represented in a simple manner in chromaticity diagrams, a different coordinate system probably will be required for each different type of observation. No one type of observation is of sufficiently general use to justify the standardization of the corresponding coordinate system in place of the generally accepted I. C. I. coordinate system. Such a coordinate system would have no real advantage over the I. C. I. system for the representation of color tolerances because color tolerances are not in general proportional to the just noticeable color differences from the standard color. The assumption of this proportionality, which would be encouraged by the standardization of a coordinate system based on just noticeable color difference data, would constitute an unjustified and misleading simplification of the problem of the determination of color tolerances. All considerations other than noticeability of color differences would be ignored by this procedure. In most problems of color tolerance noticeability of color difference must be weighted with (1) the relative objectionabilities of the several possible kinds of color variations, which depend upon the purpose for which the colors are to be used, and (2) the relative precisions attainable in different directions of color variation from the standard, which depend on the medium and process with which the color is produced. Actual practice in the establishment of color tolerances indicates that the simultaneous evaluation of the resultant of all of these considerations, by visual examination and agreement between the producers and users of the colors, is at least as satisfactory and certainly less controversial than the attempted evaluation of the separate factors of noticeability, objectionability, and attainability. Tolerances established by such agreement can be represented just as clearly on the I. C. I. chromaticity diagram as on any other chromaticity diagram. The I. C. I. diagram is recommended for such use because it has been standardized internationally and used extensively for many years, and because its use will not lead to false simplifications of the color tolerance problem.

[1] Proceedings of the 8th Session, Commission Internationale de l'Éclairage (International Commission on Illumination, I. C. I.) (Cambridge, 1931), p. 19.

[2] T. Smith and J. Guild, "The CIE Colorimetric Standards and Their Use," Trans. Opt. Soc. **33**, 73 (1931).

[3] D. B. Judd, "The 1931 I. C. I. Standard Observer and Coordinate System for Colorimetry," J. Opt. Soc. Am. **23**, 359 (1933).

[4] *Handbook of Colorimetry* (Technology Press, Cambridge, Massachusetts, 1936).

[5] D. B. Judd, "A Maxwell Triangle Yielding Uniform Chromaticity Scales," J. Opt. Soc. Am. **25**, 24 (1935).

[6] T. Smith, *The Colour Triangle and Colour Discrimination*, Report of a Joint Discussion on Vision (University Press, Cambridge, 1932), pp. 212–226.

[7] F. C. Breckenridge and W. R. Schaub, "Rectangular Uniform-Chromaticity Scale Coordinates," J. Opt. Soc. Am. **27**, 226A (1937).

[8] R. H. Sinden, "A Further Search for the Ideal Color System," J. Opt. Soc. Am. I, **27**, 124 (1937); II, **28**, 339 (1938).

6. Specification of Color Tolerances at the National Bureau of Standards. DEANE B. JUDD, *National Bureau of Standards.* (20 minutes.)—Color tolerances have been applied at the National Bureau of Standards by three methods: (1) Specification by permissible area on the mixture diagram of a fundamental colorimetric coordinate system (O. S. A. or I. C. I. systems) combined with stated tolerances restricting luminous transmission of samples viewed by transmitted light, or restricting luminous apparent reflectance of samples viewed by reflected light. (2) Use of a standard and tolerance sample, delivered goods to depart from the standard color by not more than the tolerance, amount of color departure determined by direct visual estimate. (3) Specification of the "N.B.S. unit of surface-color difference" which combines circular areas on the uniform-chromaticity-scale (UCS) triangle with a degree of lightness tolerance adjusted to the observing conditions for each particular type of sample. The combination of the chromatic and achromatic components of the unit is made by analogy with Euclidean geometry. Lightness is estimated as the square root of the apparent luminous reflectance. It is known that the presence of a conspicuous dividing line between the two surfaces to be compared interferes with the perception of the lightness difference between them but affects only slightly the perception of chromaticity difference. Also it has been found under inspecting conditions that a glossy finish on the sample interferes with the perception of color differences, the darker the samples, the greater the interference, there being little or no interference for near-white samples. Both the character of the dividing line and the gloss of the sample are taken into account in formulation of the N.B.S. unit; color differences expressed in these units are intended to be proportional to estimates of size of color difference by direct visual inspection. The derivation of the formula defining the N.B.S. unit will be given together with some of the data which have accumulated during the past 20 months since adoption of the unit. These data corroborate the formula in the main but some of them suggest that the color spacing indicated by the uniform-chromaticity-scale triangle fails significantly to accord with estimates obtained in the inspection of samples. This partial failure of the UCS triangle to represent estimated color differences between actual samples seems to be related to the fact that the psychophysical data on which the UCS triangle is based refer to macular vision, but inspection of samples for color commonly involves a visual field subtending 20 or 30 times this angle. A revision of the third method of specifying color tolerances is thus foreshadowed; our research work is directed toward the development of a unit of surface-color difference which shall take satisfactory account of the properties of the para-foveal portion of the normal retina.

7. Industrial Color Tolerances. ISAY A. BALINKIN, *University of Cincinnati and Cambridge Tile Manufacturing Company.* (20 minutes.)—The possibility of establishing object-color tolerances upon a firm scientific basis leads to two requirements: (1) Physical measurement of color and its evaluation as a numerical quantity. (2) Establishment of correlation between color differences expressed physically and visual perception of such color differences. The development of physical instruments for measuring color and adoption of standard illuminants, normal observer and standard coordinate system by I. C. I. gave the necessary essentials to satisfy the first requirement. The second requirement is still in the process of development and a brief reference will be made to several methods proposed for evaluating color differences. The degree of agreement between computed color differences and color differences individually estimated by more than 100 observers on five different colored tiles, will be presented in a graphical form. The color difference between two arbitrarily chosen tiles was designated by unity, and estimates were given on the ratio of the other nine color differences to this unit. From the standpoint of industrial color tolerances this method of establishing the validity of any proposed equation for computing color difference seems to be direct and most valuable. For the past several months many color measurements were made on Hunter's multipurpose reflectometer and color differences computed with the use of Judd's equation on the basis of transformations referred to the uniform-chromaticity-scale triangle. In all future discussions the unit of color difference as evaluated from Judd's equation will be referred to as "judd." The following two manufacturing problems will be presented and discussed: First, establishment of acceptable color tolerance. Second, industrial control of color uniformity within that tolerance. The numerical magnitude of maximum acceptable color difference within a single article or between separate articles must depend upon the specific use of that article in actual service. It is, therefore, futile to expect that a single color tolerance could ever be established. Within a specific industry or in related fields definite color tolerances could be adopted to a great profit both to the producer as well as the consumer. The most direct approach to the question of what the color tolerances should be is to present to the consumer several exhibits simulating the actual conditions of use. Each exhibit will represent a certain variation in color within determinable limits. The consumer is then to be asked to express his view on what he considers the maximum acceptable color tolerance. This procedure may not be as simple as desirable since the cost per article is very frequently connected with the magnitude of maximum allowable color tolerance. As an experiment, in the manufacture of ceramic wall tiles, five different panels will be shown in which the maximum color variation from the standard tile is made on the basis of 1, 2, 3, 4, and 5 judds. The audience will be asked to examine these panels and express their opinion on what they would consider an acceptable color tolerance. The possibility of expressing a color difference as a number has a most important practical application in the industrial control of color uniformity. In any manufacturing process there are usually several factors which determine the color of a finished article. In the ceramic industry we may consider the following factors: (1) Glaze preparation, including raw materials; (2) glaze application, determining the final thickness of the fired glaze; and (3) firing temperature. Each one of

these factors plays an independent role in determining the color of the glazed article. From the standpoint of control it is necessary to know what changes in color are introduced by the variation in each one of these factors. Any given glaze is studied by applying it in different thicknessess and firing the tiles at two extreme temperatures. The color of each tile is then carefully measured and computations made to determine the rate of color variation as a function of glaze thickness, i.e., so many judds per thousandth of glaze thickness; or as a function of firing temperatures, i.e., so many judds per degree Fahrenheit. The knowledge of such rates of change in color points directly to the factors whose control must be maintained within specific limits so that the final variation in color could be held within predetermined color tolerance. These rates are also used in classifying glazes according to their expected color variability in production. They become definite criteria for general expression of color permanency of any material by various measurable physical or chemical agents.

Graphs will be shown for a number of representative glazes.

Discussion

Exhibits on color tolerances to be open for inspection during entire day.

THURSDAY, FEBRUARY 23, AT 8:00 P.M.

POPULAR SESSION: PARADE OF COLOR

Chairman: M. Rea Paul

8. Color in Medicine. E. N. GATHERCOAL, *University of Illinois, School of Pharmacy.* (Representing the National Formulary, American Pharmaceutical Association.)—In 1931 the following request was made by the U. S. Pharmacopoeia to the Inter-Society Color Council: "A means of designating colors in the United States Pharmacopoeia, in the National Formulary, and in general pharmaceutical literature is desired; such designation to be sufficiently standardized as to be acceptable to science, sufficiently broad to be appreciated and usable by science, art, and industry, and sufficiently commonplace to be understood, at least in a general way, by the whole public." The point has now been reached where the plan for translating the great number of color names in the U. S. Pharmacopoeia and the National Formulary is taking on a very tangible form and giving results that are most interesting. A report on this activity will be presented.

9. Color in Paper. J. A. VAN DEN AKKER, *The Institute of Paper Chemistry.* (Representing the Technical Association of the Pulp and Paper Industry.)—For a number of technical reasons, accurate and objective measurement of color has become of great importance to the pulp and paper industry. The general problem is not so much one of finding the most pleasing or comfortable colors, but more a matter of increasing efficiency of production, and maintaining color standards and uniformity of color. Of unusual interest to the pulp and paper industry is "grading brightness," or the reflectance for blue light of a certain quality measured under carefully specified conditions. This measurement has become of such great technical importance that an international service for calibration of "brightness testers" has been established and is carried on as a routine and smoothly operating function. The industry is keenly interested in color specification by the method of indirect colorimetry and photoelectric spectrophotometry, and the methods of spectrophotometry are being adopted. Researches on dyeing and on the calculation of spectral reflectance curves are in active progress. In a recent research the dependence of optical properties of paper on concentration of dye in single and double dyeings was thoroughly investigated, and a method for quickly arriving at a color match was developed.

10. Color in Textiles. WM. D. APPEL, *National Bureau of Standards.* (Representing the American Association of Textile Chemists & Colorists.)—When the textile chemist and colorist contemplates beautifully colored fabrics, he is reminded of the kaleidoscopic array of stains, dyes, lakes, and pigments with which the colors are obtained. He sees the different kinds of fibers, each with its peculiar affinities, and the numerous methods of application of coloring matters to textiles. He thinks of the relationship the coloring matter, fiber, and method of application bear to the use of the product; the permanency of colors, their fastness to light, laundering and other agencies. Some of the interesting factors underlying the coloring of textiles will be pointed out for a variety of fabrics which will be exhibited, the affinity of fibers for dyes will be demonstrated, and recent developments will be described.

11. Color in Industry. H. LEDYARD TOWLE, *Pittsburgh Plate Glass Company.* (Representing the American Ceramic Society.)—Industries have definite personalities. Color in product and manufacture brings out these personalities.

12. Color in Lighting. R. G. SLAUER, *Westinghouse Lamp Division.* (Representing the Illuminating Engineering Society.)—This talk will illustrate the progress in incandescent illuminants; the achievements and limitations

in producing artificial daylight and colored light by the source alone and with appropriate auxiliary equipment; the background of gaseous discharge lamp developments; the basic value of such sources; attempts to modify characteristic line spectra; the advent of practical fluorescent sources; their general color characteristics.

13. Color in Psychology. A. H. HOLWAY AND M. J. ZIGLER, *Wellesley College.* (Representing the American Psychological Association.)—The three well-known types of dichromat—protanope (red blind), deuteranope (green blind), tritanope (blue blind)—are known to exhibit specific deviations from the (normal) trichromat in respect of visibility curves. However, a consideration of the neurophysiology of color vision suggests that the cases of color blindness now commonly distinguished are not sufficiently representative; as many as nine typical visibility curves can be specified as limiting cases. The major (quantitative) properties of these nine types are depicted graphically.

14. Color in Fashion. ELIZABETH BURRIS-MEYER, *School of Fashion Careers.* (Representing the Individual Member Group.)—This talk will be illustrated by various types of merchandise and will show, in the brief time allotted, something of the factors involved in the origin, development, manipulation and cycle of popularity of a color in the fashion business. Some of the phases of the development of a color in fashion touched upon will be: what makes a color fashion-right; why and when the consumer accepts a color and what she expects from it in decoration or dress; what is done to style, promote and merchandise the color; what happens to make a color obsolete over a period of time.

SATURDAY MORNING AT 10:00 O'CLOCK

National Broadcasting Company

RCA Building, 30 Rockefeller Plaza

Studio 3A

Joint Session of the American Physical Society, the Optical Society of America and the Inter-Society Color Council

SYMPOSIUM ON TELEVISION

Invited Papers

1. **Electron Optics as Applied in Television Systems.** V. K. ZWORYKIN, *RCA Manufacturing Company*
2. **Application of Electron Multipliers to Voltage Amplification.** P. T. FARNSWORTH, *Farnsworth Television, Incorporated*
3. **Demonstrations in Television.** A. F. VAN DYCK, *Radio Corporation of America*

Cards of admission will be required for this symposium and may be obtained by members of the societies without charge at the registration desk in Pupin Physics Laboratories on Friday.